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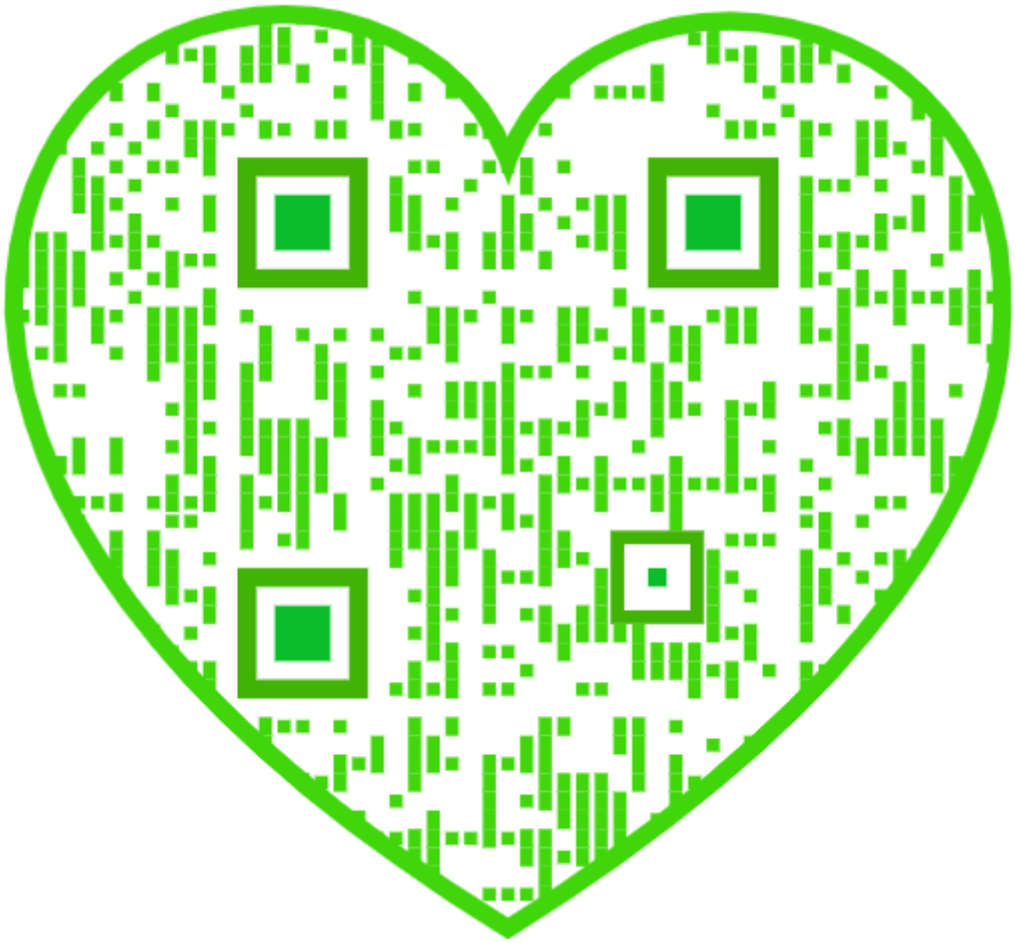

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ENGINEERING SOCIETY SCHOOL OF PRACTICAL SCIENCE, TORONTO.

THE

STEAM ENGINE,

ITS ORIGIN AND GRADUAL IMPROVEMENT,

FROM THE TIME OF HERO TO THE PRESENT DAY;

AS

ADAPTED TO MANUFACTURES, LOCOMOTION AND NAVIGATION.

BY P. R. HODGE, C. E.

WITH NUMEROUS EXPLANATORY WOOD CUTS, AND A VOLUME, CONTAINING

FORTY-EIGHT PLATES,

NEW-YORK:
D. APPLETON & CO., 200 BROADWAY.
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Dedicated

TO

THE MECHANICS OF THE UNITED STATES OF AMERICA,

BY THE AUTHOR.

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INTRODUCTION.

To supply the Mechanic with a concise history of the invention and subsequent improvements of the Steam Engine, from the earliest period to the present time, together with such practical rules and explanations as would enable him to design and construct a machine of any required power, and of the most improved form, for whatever purpose desired, has been the main object of the Author of this volume.

For the purpose of rendering the reference from the letter-press to the plates as convenient as possible, it was deemed advisable to have the engravings in a separate volume, thereby enabling the author to have them of such a size as would be practically useful to the workman, instead of being merely illustrations of the letter-press.

The plates being all drawn to certain scales, the dimensions of every part may be taken and machines built from any of the designs.

The various engines have been selected as being the most improved of their respective classes, and with four exceptions only, are all of American construction and arrangement; thus exhibiting, for the first time, the rapid march of improvement which this enterprising country has taken during the last few years in the science of engineering.

How far the Author may have succeeded in his endeavours to supply this desideratum—"A practical work on the Steam Engine"—is a question to be decided by the intelligent and and enlightened citizens of the United States.

New-York, Oct. 1840.

THE

STEAM ENGINE,

BY

P. R. HODGE, C. E.

PART I.

HISTORICAL ACCOUNT OF THE

STEAM ENGINE,

FROM THE EARLIEST PERIOD TO THE

PRESENT TIME.

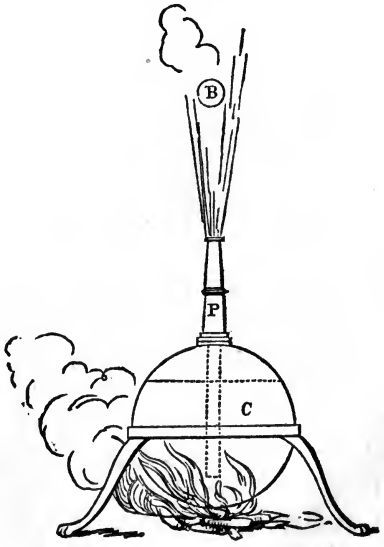
HISTORICAL ACCOUNT

OF THE

STEAM ENGINE, &c.

From the earliest ages, mankind must have been acquainted with the fact, that the application of heat would turn water into vapour, and that such vapour would rush through any aperture in the vessel containing it, with a considerable degree of force; but the application of this vapour to useful purposes, the employment of this force as a mechanical agent, is comparatively of recent date.

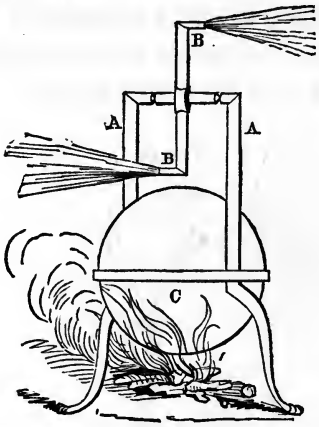
Figure I.



Hero the elder, who flourished at Alexandria in the reign of Ptolemy Philadelphus, about 130 years before the Christian

era, and was eminently distinguished for his learning and for the number and ingenuity of his mechanical inventions, is the first who gives any account of the application of the vapour of water. In his work, entitled *Spiritalia*, or Pneumatica, he describes, amongst many others, two machines which operate by the force of steam. The first (figure 1) is a caldron or vase C, containing boiling water, with a pipe P reaching nearly to its bottom. As the steam accumulates in the top of the vessel, it presses on the surface of the water, and will force it in a continued jet through the pipe, till the whole is ejected or converted into steam. A fountain may thus be formed capable of supporting the ball B.

FIG. II.



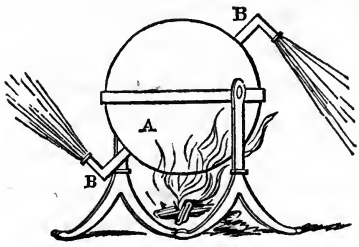
The second (fig. 2) consists of a similar vessel C, which is closely covered with a lid, having two pipes A A, which after rising vertically for a short distance, are bent towards each other, and serve as pivots to support the hollow arms B B, in which are openings corresponding to those in the pipes. These arms are furnished with two open tubes, and placed diametrically opposite to each other, and bent at their extremities in contrary directions, and at right angles to the axis of the globe. The stream from the water in the vessel rises through the pipes into the globe, and issuing through the tubes causes the globe

to revolve, in the same manner as water produces the rotary motion of Barker's mill. Though this apparatus is described as a mere philosophical toy, and not the slightest hint is given that the invention was capable of any useful application; it is curious, as being the earliest instance we are acquainted with, of the employment of steam to produce motion; thus conferring on Hero the honour of having invented and constructed the first steam engine. Hero also expressly ascribes the sounds which issued from the statue of Memnon to the action of steam. If this be correct, we have an instance of the application of steam to (we will not say a useful, but to) a specific purpose, as early as 1600 years before Christ. But we are of opinion with Professor Renwick, "that this is rather an ingenious explanation by the philosopher himself, of the mode in which he could have effected the same object, than an account of what was really performed by the Egyptian priests."

The description of these machines sufficiently establishes the fact, that the ancients were acquainted with both the expansive and impulsive force of steam. Our information from other sources is exceedingly scanty and imperfect, and is chiefly incidental. The Oelipile appears to be the only instrument used by them to display its power, and that was applied to only one object: to excite combustion. How it was used for that purpose is not explained, and, as steam itself will not support combustion, remains a matter of conjecture. Vitruvius, in his treatise on Architecture, Lib. 1. Cap. VI. refers to the œlipile as an illustration of the causes of winds.

Fig. 3 is a representation of this instrument; which consists of merely a globe or other hollow vessel A, containing a small quantity of water, and having spouts or tubes, B B. The vessel being placed over a fire, the water is converted into steam, and will issue forcibly from the tubes. If the œlipile be placed on wheels, it will recoil by the reaction of the steam, as it escapes; and a rotary motion may be obtained by employing two tubes, as in the machine of Hero. In this form it is called the whirling œlipile.

Fig. III.

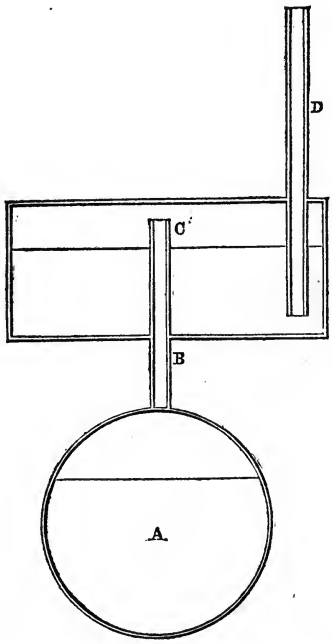


We find no further notice of steam being applied to any purpose, either of use or amusement, till after the revival of learning; and the earliest modern writers we meet with who speak of its mechanical properties, are Cardan and Mathesius. The latter, in a volume of sermons, published about 1760–'63, hints at the possibility of constructing an apparatus similar in its operation and properties to the modern steam engine, and "displayed almost as much ingenuity in contriving to introduce so untoward a subject into a sermon as would be required to invent the machine itself, and which he gives as an illustration of what mighty effects could be produced by the volcanic force of a little imprisoned vapour."

Cardan, who (to quote Renwick) "united all the learning of his age to even more than all its superstition," is the first among the modern writers who mentions the œlipiles, and seems to have been acquainted, not only with the expansive force of steam, but also the fact that a vacuum could be produced by its condensation. About thirty years after this period, the "whirling œlipile" is proposed to supersede the turnspit dog in the honorable discharge of his culinary duties. Whether this substitution of machinery for manual labour was prevented by remonstrance or petition on the part of the domestics whom it would so cruelly turn out of employment, is not on record; but, from one of the reasons urged for its adoption, it appears that in this, as in other cases, the bad conduct and dereliction from honesty of some of these useful laborers, endangered the subsistence of the whole. The projector states that his machine

" eats nothing, and gives, withal, an assurance to those partaking of the feast, (whose suspicious natures nurse queasy appetites,) that the haunch has not been pawed by the turnspit (in the absence of the housewife's eye,) for the pleasure of licking his unclean fingers."

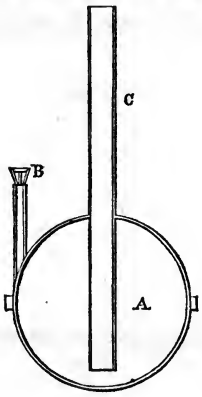
Fig. 1V.



The next we find worthy of notice is Baptista Porta, a Neapolitan. He describes his apparatus in an Italian translation of Hero's work, published 1606. It is remarkable as being the first in which the steam is applied to force up cold water from a separate vessel, instead of driving up the hot water, from which it is produced. The boiler A (fig. 4) has a neck or tube B, through which the steam passes to the upper part of the close cistern C, and, passing on the surface of the water it contains, forces it up the pipe or syphon D. The contrivance in this respect is similar to, and would seem to be the germ of, that

of the Marquis of Worcester, from which it differs but little, except in the extent of its power.

Fig. V.



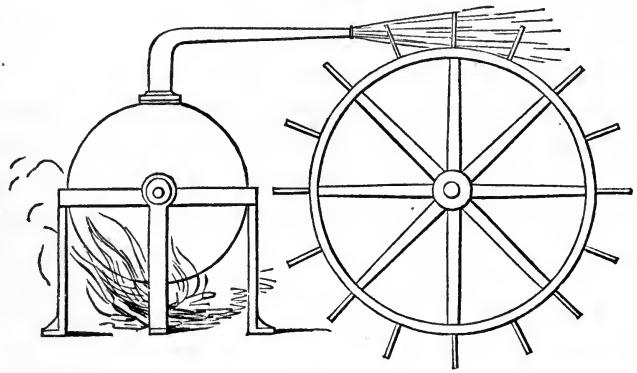
In 1615, Solomon De Caus, a native of Normandy, eminent as an engineer and mathematician, published a work on Moving Forces and Machines, in which is to be found the following contrivance for applying the expansive force of steam. He says: "Let there be a globe A, (fig. 5) having a valve B to introduce water, and a tube C soldered into the upper part of the ball, and descending nearly to the bottom. After having filled the ball with water, and well closed the valve, place it on the fire; then the heat acting on the ball will cause the water to ascend through the tube." This apparatus (on which M. Arago claims for the French the honor of inventing the steam engine) is not only inferior to that of Porta, but had been anticipated in all but the valve by Hero.

De Caus was also acquainted with the fact that steam could be condensed into its own weight of water; but he appears to have known no mode of applying this property to aid the effect of his fountain.

The machine of Giovanni Brancas, an eminent Italian mathematician, who lived at Rome in the commencement of the seventeenth century, next claims our attention, being the first in which the power of steam was proposed to be used for any

other purpose but that of raising water. His machine was applied to pounding drugs, and he published his account of it in 1629. It consisted of an œlipile (fig. 6), the blast of which was directed against a wheel formed with float-boards, or vanes, similar to a water-wheel or wind-mill. A rotary motion was thus produced, which, by the aid of intermediate mechanism, worked the stampers or pounders. We afterwards find Bishop Wilkins and Father Kircher proposing similar machines—the latter recommending to employ two œlipiles; and Philibert de l'Orme proposing to use the blast of the œlipile to drive smoke up a chimney.

FIG. VI.



A note to a Spanish work lately published, consisting of original papers relative to the voyages of Columbus, contains a very curious account of an experiment made at the port of Barcelona, in the year 1543, in the presence of the Emperor Charles V., Prince Philip, and several officers of state. A ship of 200 tons burden was propelled by machinery, and it is stated that the experiment was altogether so successful, and that the ship tacked so expertly, that the Emperor and his suite highly applauded the performance, and Garey was handsomely rewarded. The whole of the engine could not be seen, but, from the part exposed, it was observed to consist of a large vessel of boiling water, with moveable wheels at each side of the ship. When the exhibition was over, Garey took the engine from the ship, and, depositing the wood-work in the arsenal of Barcelona, kept the rest himself.

This account, copied from the Royal Archives of the city of Salamanca, was communicated to the author of the work, August 27, 1825, by one Thomas Gonzales. According to Sir Richard Phillips, the facts cannot be

These were the only methods suggested for the application of steam to mechanical purposes previous to that of the Marquis of Worcester. How far they had been put in practice, or, indeed, if any one of them had been actually used, is very doubtful; but the Marquis most undoubtedly did succeed in constructing a machine for raising water, in which the expansive force of steam was employed as a source of motion. His account of the invention is contained in a work, the original manuscript of which is preserved in the British Museum. It is entitled "A Century of the Names and Scantlings of Inventions," and was written in 1655, and first appeared in print in 1663. We there find the following Name and Scantling:

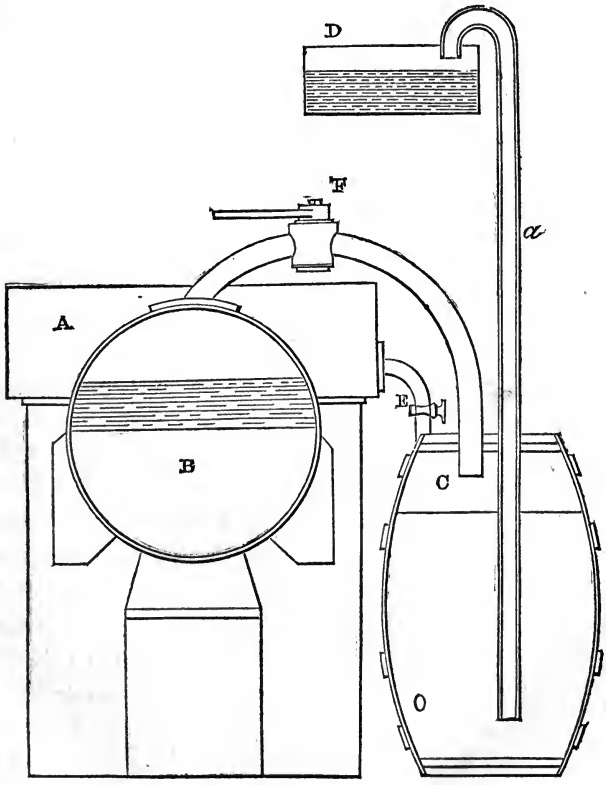
"LXVIII. A Fire Water-Work.—An admirable and most forcible way to drive up water by fire, not by drawing or sucking it upwards; for that must be, as the Philosopher calleth it, *infra sphœram activitatis*, which is but at such a distance. But this way hath no bounder, if the vessels be strong enough; for I have taken a piece of a whole cannon, whereof the end was burst, and filled it three-quarters full of water, stopping and screwing up the broken end, as also the touch-hole, and making a constant fire under it; within twenty-four hours it burst and made a great crack; so that, having a way to make my vessels so that they are strengthened by the force within them, and the one to fill after the other, I have seen the water run, like a constant fountain-stream, forty feet high. One vessel of water, rarefied by fire, driveth up forty of cold water. And a man that tends the work is but to turn two cocks, that, one vessel of water being consumed, another begins to force and refill with cold water, and so, successively, the fire being tended and kept constant; which the selfsame person may likewise

doubted—who further observes that the invention was laid aside, "owing to the bigotry of an imperial officer, one of those slow sailing intellects which in every age obstruct improvement." If it be true, the honor of first navigating a ship by steam belongs to Blasco de Garey, as also that of constructing the first efficient steam engine.

abundantly perform in the interim between the necessity of turning the said cocks."

This description is too vague for us to determine the precise form of his machine, and in consequence, many ingenious plans for the construction of an engine answering the terms proposed have been given by different writers. Among these the most complete and simple elucidation of the invention is to be found in Tredgold, from whom we copy the annexed figure and description:

FIG. VII.



"B (fig. 7) is the boiler; C one of the vessels, with a pipe to deliver the water to an elevated cistern, D. Now suppose the vessel C to be supplied from a cistern of cold water A by a

pipe, so that it should be filled on opening the cock E, and afterwards closing it; if, when the steam in the boiler is of sufficient strength, the cock F be opened, the pressure of the steam on the water in C would cause it to ascend from C, through the pipe *a*, into the cistern D. The vessel C being emptied, and the cock F being shut, it would refill with water, on again opening the cock E. Another vessel C and its cocks and pipes, are necessary to complete the species of water engine indicated by the description, and these may be on the other side of the boiler."

We may observe here, that only the expansive power of steam is employed, for the Marquis does not appear to have any knowledge of condensation. His application of steam was necessarily very expensive, from the great condensation produced on the steam coming in contact with the cold water. His mode of operation was, however, perfectly capable of producing the effects stated, he merely raising 20 cubic feet, or 1,250 lbs. of water one foot, by one pound of coals, being about the 200th part of the effect of good modern engines.

The Marquis declares, in his title page, that he has "tried and perfected" the extraordinary inventions he describes; but, from the studied brevity and obscurity of those descriptions, it was long doubted whether he really did effect any of the things he pretends to. He has been designated as a "fantastic and credulous mechanic," and his book pronounced to be "an amazing piece of folly;" however, many of his schemes have been unexpectedly realized in later times, and it has been satisfactorily proved, not only that a *fire-engine* could be constructed, "fulfilling the conditions of the enigma, and no more," but that he himself had one in successful operation. In 1818 was published a translation of a manuscript left by Cosmo de Medicis, Grand Duke of Tuscany, narrating his travels in England, in the year 1656, in which we find the following account of this machine:

"His Highness, that he might not lose the day uselessly, went again, after dinner, to the other side of the city, extending

his excursions as far as Vauxhall, beyond the palace of the Archbishop of Canterbury, to see an hydraulic machine, invented by Lord Somerset, Marquis of Worcester. It raises water more than forty geometrical feet, by the power of one man only, and, in a very short space of time, will draw up four vessels of water through a tube or channel not more than a span in width."

We think we may now dismiss his lordship, with the acknowledgment that to him is due the merit of having first practically applied the expansive power of steam to purposes useful to society.

In 1682, we find Sir Samuel Moreland endeavouring to obtain the patronage of Louis XIV. of France to a scheme for raising water by the force of steam, on apparently a similar principle to that of Worcester's ; but which he claims as his own. The manuscript which contains his proposal is preserved among the Harleian MSS. in the British Museum. It is in the French language, beautifully written on vellum, and highly ornamented, and it purports to be an account of machines for raising water. The part which treats of steam is entitled, " The Principles of the New Force of Fire, invented by Chevr. Morland, in 1682, and presented to his most Christian Majesty in 1683." In this year, he exhibited his invention before the French king at St. Germains. We have no description of his apparatus or its mode of action. His explanation of his theory is as follows:—

" Water being converted into vapour by the force of fire, these vapours shortly require a greater space (about 2000 times) than the water before occupied ; and sooner than be constantly confined, would split a piece of cannon. But being duly regulated according to the rules of statics, and by science reduced to measure, weight, and balance, then they bear their load peaceably (like good horses), and thus become of great use to mankind, particularly for raising water, according to the following table, which shows the number of pounds that may be raised 1800 times per hour, to the height of six inches, by

cylinders half filled with water, as well as the different diameters and depths of the said cylinders.

Cylinders.		Weight of the load to be raised, in pounds.
Diameter in feet.	Depth in feet.	
1	2	15
2	4	120
3	6	405
4	8	960
5	10	1875
6	12	3240

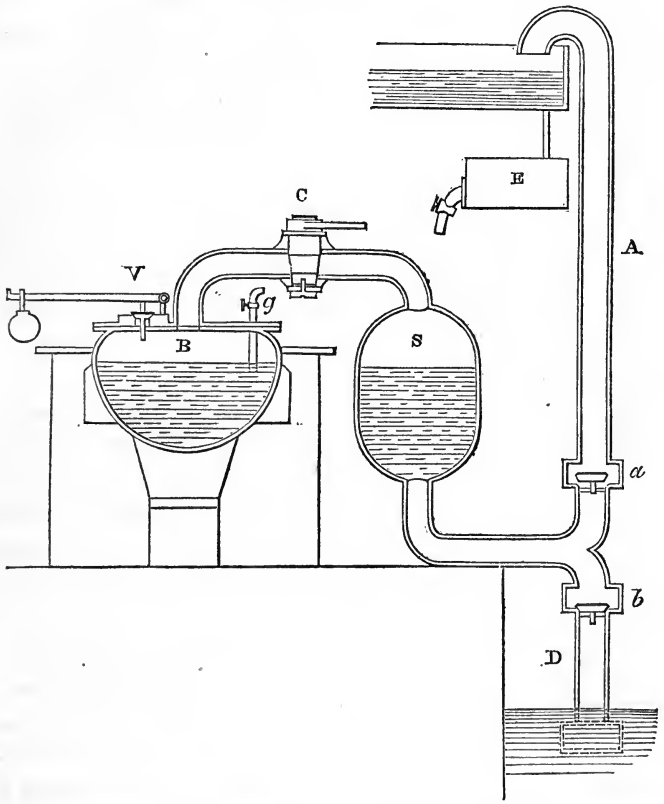
The table is extended to show the amount of water that can be raised by any number (from 1 to 90) of the largest of the above cylinders, each cylinder being 6 feet in diameter, 12 feet in length, and capable of raising 3240 lbs. weight of water.

He also gives the rate of the expansion of water when converted into steam at common atmospheric pressures, so nearly correct, that we may fairly conclude it to be the result of actual and careful experiment. The general character of his statement, and particularly his mention of the cannon, would lead us to conclude that the idea of his projected engine was borrowed from the Marquis' work, published twenty years before; but at all events, he is entitled to the merit of being the first accurate experimenter on the elastic force of steam.

The next practical application of steam power was made by Captain Savery (also an Englishman), who was the first to publish a method of producing a vacuum by the condensation of steam; and combining this with the elastic force employed by Worcester, he constructed an engine for raising water, for which he had letters patent granted in 1698; being the first patent on record for a steam engine. In 1699, he published a pamphlet, entitled "The Miner's Friend," in which he described his machine, several of which, according to Dr. Robison, had been erected previous to the patent being obtained. In June, the same year, he exhibited a model of his engine before the

members of the Royal Society, who were perfectly satisfied with the success attending his experiments.

Fig. VIII.



It consisted of a furnace and boiler B (fig. 8); from the boiler two pipes, provided with cocks C, proceeded to two steam vessels S, which had branch pipes from a descending main D, and also to a rising main pipe A; each pair of branch pipes had valves *a*, *b*, to prevent the descent of the water raised by the condensation, or by the force of steam. Only one vessel S is shewn in the cut, the other being immediately behind it. One of the steam vessels being filled with steam, condensation was produced by projecting cold water from a small cistern E

against the vessel, and into the partial vacuum made by that means, the water by the pressure of the atmosphere was forced up the descending main D from a depth of about twenty feet; and on the steam being let into the vessels again, the valve *b* closed, and prevented the descent of the water; while the steam, having acquired force in the boiler, its pressure caused the water to raise the valve *a*, and ascend to a height proportional to the excess of the elastic force of the steam above the pressure of the air.

g, The guage cock for ascertaining the level of the water.

In subsequent engines, he employed only one steam vessel, and further improved his machine by the application of Papin's digester or safety valve V, and making use of a small boiler to heat water for the large one, in order to prevent loss of time.

It is uncertain whether Savery was acquainted or not with the ideas of his predecessors. His claims to originality, and to the discovery of condensation, have been much questioned by Desaguliers, who also charges him with having bought up and destroyed all the copies of Worcester's book on which he could lay hands, in order to keep to himself the whole credit of the invention. This grievous charge, as Dr. Robison well observes, ought to be substantiated by very distinct evidence — "yet Desaguliers produces none such; and he was too late to know what happened at the time." Besides, Savery's own account is so clear and distinct; such a liberal and honest appeal to experiment pervades the whole; and it is so free from the self-sufficiency and conceit too generally to be found in works of the kind, that we cannot help giving credit to his statement.

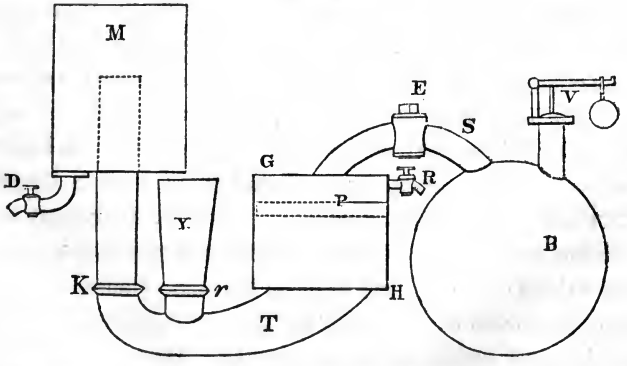
Under any circumstances, his original invention was considerable, and his machine very superior to that of the Marquis. To him is due the merit of the first use of condensation and the safety valve, the employment of a vessel to supply the boiler with hot water, and the use of the guage cock to ascertain the quantity of water in the boiler.

The defects of his machine were, great waste of steam from the cold vessel and cold fluid; and the machinery could not be

made available for mining purposes, as water could not be raised to a sufficient height without the use of such powerful steam as to become dangerous.

In 1690, Dr. Denys Papin, a French Protestant, first suggested using the alternate action of steam and air to produce motion. He proposed "turning a small surface of water into vapour by fire, applied to the bottom of the cylinder which contains it, which vapour forces up the plug or piston in the cylinder to a considerable height; and which, as the water cools, *when taken from the fire*, descends again by air's pressure, and is applied to raise water out of the mine"—a mode of operation so impracticable, that notwithstanding the aid he received from Libnitz, in prosecuting the idea, he was obliged to abandon his scheme. It appears that, in 1698, by command of Charles, Landgrave of Hesse (to whom he gives the credit of the first idea of a steam engine), he made several experiments, but without any useful result. Having seen an engraving of Savery's engine in 1705, he resumed his experiments, and published a tract on the subject in 1707; but notwithstanding his knowledge of what Savery had done, his most improved engines were incapable of performing more than had already been accomplished by Worcester.

FIG. IX.



His machine consisted of a boiler B (fig. 9), provided with a safety valve V, and a cylinder G H, connected to the boiler

by the steam pipe S. The cylinder was closed at the top, and contained a floating piston P ; and the base of the cylinder terminated in a curved tube T, which ascended into a cylinder M ; the bent tube had a pipe Y from a reservoir of water communicating with it, and it was provided with a valve at *r*. Now suppose the cylinder G H to be filled with cold water by the pipe Y from the reservoir, and the boiler to contain strong steam ; by opening the cock E, the steam would be admitted, and pressing on the floating piston P, cause the water to ascend in the cylinder M ; its return is prevented by the valve K, and the steam cock E being shut, and the cock R opened to let the condensed steam escape at the pipe R, the water from the reservoir refills the steam cylinder through the pipe Y, and is ready for repeating the operation. The water raised can be directed to any useful object by the pipe D.

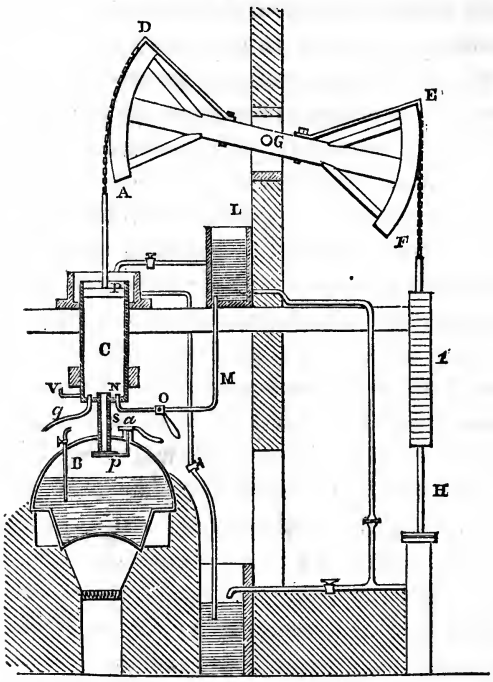
He is principally famous as the inventor of the safety valve and the four-way cock, without the former of which, it is not improbable that steam would have been abandoned long ago as a most dangerous and ungovernable agent. Mankind are, moreover, considerably indebted to him for his proposal to use the joint powers of steam and air. This idea, when actually reduced to practice by Newcomen in his atmospheric engine, was productive of such favourable and beneficial effects, that the attention of scientific men was irresistibly attracted to steam power, and a course of experiments and investigations entered on, which otherwise they might never have been induced to attempt. Dr. Papin also suggested that the water raised by his engine might be used to turn a wheel, and so impel other machinery.

Amontons, a distinguished member of the French Academy of Sciences, presented to that body, in 1699, an account of an invention, which he calls a Fire Wheel, and which has induced most writers on the subject to place his name among the inventors of the steam engine ; but the machine he describes can be considered as nothing but an air engine. He proposes, by the alternate application of fire and cold water, to cause an expansion and contraction of air, so as to produce motion.

Notwithstanding the imperfections of Savery's machines, it now became sufficiently evident that steam could be used effectively for raising water, and the want of some cheap and powerful agent for that purpose, rendering the working of deep mines so expensive, as to be almost ruinous to the proprietors, though otherwise highly productive. An immense prospect of advantage opened to any one who could, either by overcoming the defects in Savery's invention, or by otherwise adapting the power of steam, succeed in obtaining sufficient power to work such mines profitably. These incentives producing further researches and experiments, the result was a new construction of the steam engine, by Thomas Newcomen, a smith, of Dartmouth, Cornwall; and in 1705, he obtained a patent for his invention, conjointly with John Cawley, a plumber, also of Dartmouth, and Captain Savery, who was associated with them on the ground that their machine interfered with his previous patent. The principal novelty of this construction consisted in condensing the steam under an air-tight piston in a cylinder open at top: thus applying atmospheric pressure. The idea was probably borrowed from Papin; for Dr. Hook, who was well acquainted with Papin's speculations and experiments, seems to have held a correspondence with Newcomen on the subject of steam power. However, Newcomen's mode of effecting his object was altogether different from any proposed by the Frenchmen. The following is a description of Newcomen's engine in its improved state.

"B (fig. 10) represents the boiler, with its furnace for producing steam; and at a small height above the boiler is a steam cylinder C of metal, bored to a regular diameter, and closed at the bottom, the top remaining open. A communication is formed between the boiler and the bottom of the cylinder, by means of a short steam-pipe, S. The lower aperture of this pipe is shut by the plate *p*, which is ground flat, so as to apply very accurately to the whole circumference of the orifice. This plate is called the regulator, or steam-cock, and it turns horizontally on an axis, *a*, which passes through the top of the

Fig. X.



boiler, and is fitted steam-tight, and has a handle to open and shut it. A piston P is fitted to the cylinder, and rendered air-tight by a packing roun d its edge, of soft rope, well filled with tallow, to reduce the friction, and its upper surface is kept filled with water to render it steam-tight. The piston is connected to a rod P A, which is suspended by a chain from the upper extremity D of the arched head of the lever, or working beam, which turns on the gudgeon G. This beam has a similar arched head E F at its other end, for the pump rod H, which receives the water from the mine. The end of the beam to which the pump-rod is attached, is made to exceed the weight and friction of the piston in the steam cylinder; and, when the water is drawn from such a depth, that the steam piston is too heavy for this purpose, counterpoise weights must be added at F, till the piston will rise in the steam cylinder, at

the proper speed. At some height above the top of the cylinder is the cistern L, called the injection cistern (supplied with water from the forcing pump H). From this descends the injection pipe M, which enters the cylinder through its bottom, and terminates in one or more small holes at N. This pipe has a cock at O, called the injection cock, fitted with a handle. At the opposite side of the cylinder, a little above its bottom, there is a lateral pipe, turning upwards at the extremity, and provided with a valve at V, called the snifting valve, which has a little dish round it to hold water for keeping it air-tight. There proceeds also from the bottom of the cylinder a pipe *q*, of which the lower end is turned upwards, and is covered with a valve; this part is immersed in a cistern of water called the hot well, and the pipe itself is called the eduction pipe. To regulate the strength of the steam in the boiler, it is furnished with a safety valve, constructed and used in the same manner as that of Savery's engine, but not loaded with more than one or two pounds on the square inch."

Mode of Operation.—"The piston being at the bottom of the cylinder, and the regulator or steam-valve being shut, it will be kept there by the pressure of the atmosphere. Apply the fire to the boiler till the steam escapes from the safety valve, and then, on opening the steam-regulator, the piston will rise by the joint effect of the strength of the steam and action of the excess of weight on the other end of the beam. When it arrives at the top of the cylinder, close the regulator *p*, and by turning the injection-cock O, admit a jet of cold water, which condenses the steam in the cylinder, forming a partial vacuum, and the piston descends by the pressure of the atmosphere, raising water by the pump rod from the mine. The air which the steam and the injection water contains is impelled out of the snifting valve V, by the force of the descent, and the injection water flows out at the eduction pipe Q; and by the repetition of the operations of alternately admitting steam and injecting water, the work of raising water is effected."

The steam was condensed in his early engines by the appli-

cation of cold water to the outside of the cylinder. Desaguliers says, the idea of injection was the result of accident—"as they were working they were surprised to see the engine go several strokes, and very quick together; when, after a search, they found a hole in the piston which let the cold water in to condense the steam in the inside of the cylinder; whereas, before they had always done it on the outside." This being observed, the injection cock was soon added to the machine.

A further improvement is the addition of contrivances for opening and shutting the cocks and valves by the action of the engine, thus rendering it more nearly a self-regulator, was brought about through the idle ingenuity of a boy named Humphrey Potter; who, that he might have time to play, found means to open and shut them by attaching strings and catches to the working beam. The engine was brought to this simple and efficient degree of perfection about 1712, and such engines were erected in several places. It was called, in this state, the Atmospheric Engine.

The merit of this engine has been said to lie chiefly in its mechanism, but that mechanism makes it efficient, and therefore practically of much value. It is one thing to suggest the particular application of a certain principle, and another to follow out such suggestion to a practical result. Tredgold very pertinently remarks:

"To point out what is actually due to Newcomen would be difficult; and, for want of evidence, we must be content with examining the state of the engine. The admission of steam below an air-tight piston, attached to the impelled point of a lever properly counterpoised; its rapid condensation by the injection of water, which is essential to gain effect; and the mode of clearing the cylinder of air and water after the stroke, are all additional to the principles and mechanism before in use, and these are wholly due to Newcomen, or those connected with him."

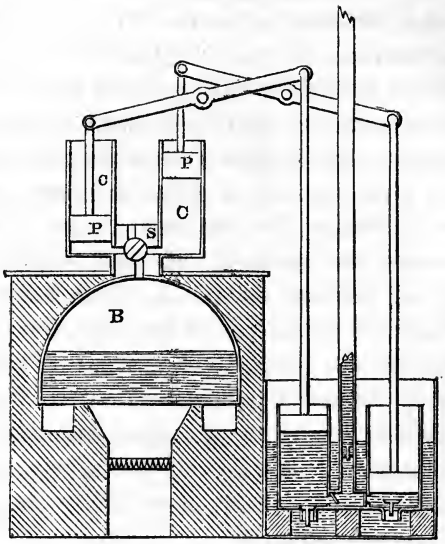
Henry Beighton, an engineer of Newcastle-upon-Tyne, directed the construction of several engines. He was the first

who reduced the calculation of steam power to any regular system. The table published by him in 1717, of "the Dimensions and Power of the Steam Engine," has been found to be generally correct. It was Beighton who first noticed the fact that steam would heat a considerable quantity of water during condensation. He made many experiments as to the bulk of steam produced from a given quantity of water, and communicated his experiments to Desaguliers, but from a mistake in his calculation his result was incorrect. He improved the machinery for opening and shutting the valves, which before him was little more than the contrivance of the boy Potter, consisting merely of strings and catches. Beighton first adopted rods, connected with the working beam. He also evinced much judgment in his manner of fixing engines, and his arrangement of the different parts. His views were not very novel, but he possessed sound scientific knowledge, which, perhaps, was productive of more practical good.

The accounts we have of different engines by various projectors about this time, are sufficiently numerous; but as they do not contain any thing new, either in theory, experiment, or construction, they are hardly worthy of notice. But an illustrious German, named Leupold, was a man of superior character. His engine, constructed 1720, is admirable for its extreme simplicity, but is more remarkable, from being the first combination of the working beam and cylinder with the high-pressure principle, thus constituting the earliest high-pressure engine.

Over a boiler B (fig. 11), he placed two cylinders C C, fitted with steam-tight pistons P P. A four-way steam-cock S is placed between the boiler and cylinders, so as to alternately admit steam into one cylinder and let it out from the other. The piston, by the admission of strong steam from the boiler below it, is raised, and depresses the other end of a lever connected to the rod of a plunger of a pump, which causes the water to rise through the pipe, and, by the alternate action of the steam in the two cylinders, a continual stream of water is raised. As Papin was the inventor of the four-way cock, and

FIG. XI.



the first who proposed to raise a piston by steam, Leupold, with a rare degree of modesty and candour, ascribes the merit of this machine to him, but the mode of working out the principle is certainly due to his own ingenuity.

Dr. Desaguliers wrote much, but added nothing to the existing knowledge of the steam engine; though we might have expected much, from his fondness of experimental philosophy, and the opportunities he had of knowing what was going on in the scientific world. He was, besides, much prejudiced for and against individuals; his work is, therefore, only valuable as a depository and record of facts.

By this time, the atmospheric engine, with Beighton's improvements, was in very general use for raising water from coal and copper mines, but, excepting the experiment of Blasco de Garey [see note, p. 17,] there does not appear to have been any attempt to apply steam power to any other useful purpose. Savery, indeed, among other suggestions, hints at the possibility of employing this mighty power in navigation, but says he dare not meddle with that matter; and he leaves it to "the

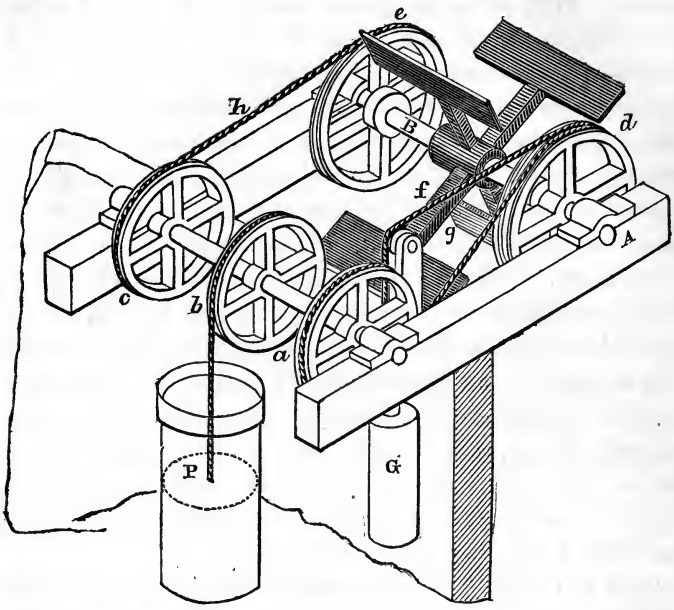
judgment of those who are the best judges of *maritian* affairs." With these exceptions, Jonathan Hulls, of London, is entitled to the merit of being the first who proposed or attempted the construction of a steamboat. He obtained letters patent for his project, in 1736, and published them, with a description of his boat, in 1737, in a tract, which is now extremely scarce, entitled, "A description and Draught of a new-invented Machine for carrying Vessels or Ships out of, or into, any Harbour, Port, or River, against Wind or Tide, or in a Calm." He contrived a method of converting the reciprocating motion of the piston into a continuous circular motion. Tredgold gives a cut of this invention, and very justly remarks, that, though it is less simple than the crank, it is "certainly a beautiful contrivance for rendering so irregular a first mover equitable, and, considering the object it was intended for, it is not a complex arrangement; for, besides equalizing the power, it gives a means of increasing or diminishing the velocity in the ratios of the diameters of the wheels."

"Let *a*, *b*, *c* (fig. 12), be three wheels on one axis, and *d*, *e* two wheels loose on another axis A, with ratchets, so as to move the axis only when they move forward; *f*, *g*, *h* are three ropes, and P is the piston of the engine. When the piston descends, the wheels *a*, *b*, *c* move forward, and the ropes *g*, *h* cause the wheels *e*, *d* to move the wheel *e* forward, and the wheel *d* backward, and the latter raises the weight G, which moves the wheel *d* forward during the descent of the piston; consequently, the axis A B, with the paddle-wheels, would be constantly moved round in the same direction and with an equable force."

From the ingenuity and information displayed in his little work, we feel assured that Hulls was a man of considerable ability, and cannot help regretting that his views should have shared the fate of too many other useful projections, in not meeting the encouragement they so evidently merited.

Though our sketch is intended to be confined to those who either theoretically or practically improved the steam engine, we cannot altogether pass by Belidor, an eminent French writer

Fig. XII.



on Engineering, civil and military; who deserves mentioning, on account of his historical sketch of the steam engine (1739). He very industriously and candidly examines the different claims to the honour of the invention, and concludes that it belongs to the Marquis of Worcester; who, he says, first gave the idea to the world in an intelligible form. After giving a description of an engine erected at Frisnes, near Condi, he states that up to that time all fire engines, whether constructed in or out of England, had been made by English workmen. His work is valuable from its extensive research, and the minute, clear, and practical style in which it is written—a style almost peculiar to himself, and which distinguishes all his productions. In other respects the book is of little use, as he added nothing to the existing knowledge of the action of steam; and his rules for the calculation of steam power are both complicated and inaccurate.

The first attempts, by direct experiment, to ascertain the

density of steam, were made by John Payne, and an account of them published in the Philosophical Transactions, vol. 41. (1741.) His process was ingenuous, but, from neglecting to use a thermometer, the results were unsatisfactory.

"He took a copper globe, twelve inches in diameter, having two cocks fitted to it, and a small valve. The vessel thus prepared was hung over a large vessel, in which water was rarefied into steam, and by a pipe the steam was admitted at one of the cocks into the globe, and the other being also open, the steam being allowed to blow through, forced out the air that was in the globe, and supplied its place; when both cocks were suddenly shut, and the globe taken down and hung over a vessel of cold water, with the lower cock immersed in water. The cock was opened under water, on which the water rushed violently into the globe, till it had supplied the vacuum, when the cock was again shut, and the globe, with the water, was put in the scales, and found to weigh 713 ounces, which, taken from 727 ounces, the whole weight before, there remains only 14 ounces for the difference; from which he inferred that all the air was nearly excluded out of the globe by the steam. He again excluded the air out of the globe with steam as before, and both the cocks being closed, with the globe full of steam, he put the globe in the scale, and it weighed 2035 ounces. He then opened one of the cocks, and let in the air, and by adding weight in the other scale, it was found to weigh 203 ounces, which showed that the weight of the air the globe contained was 5 ounces, or 218.75 grains. The globe being filled with steam as before, and condensed with cold water on the outside of the globe, and the metal again made very dry, and the air let into the globe, the water from the condensed steam was found to weigh 96 grains. It is worthy of remark here, that this gives the density of steam at 212° to that of air at 60°, as 96 : 218. 75, or, as 0. 44: 1. The true density of steam at 212° is nearly as 0. 48: 1.

The globe was filled with steam as before; only, not knowing the effect of temperature, he continued the globe longer

with the steam passing through it, by which it acquired a greater degree of heat; for he found by these experiments, that the least degree of cold, less than the steam, would condense a part of it again into water, and hence the quantity could not be ascertained which would exclude the air out of a given space, which was the chief end of the experiment. In this experiment, he succeeded in excluding the air with less steam; for, on weighing the globe, when the steam was condensed, the air let in, and all cold, it was found that the weight of the water condensed from the steam was only about 48 grains, which filled, when converted into steam, 925 cubic inches of space, so as to exclude nearly all the air. From which he concluded that one cubic inch of water will form 4,000 inches of steam. To admit of comparison, the temperature should have been observed, as there is little doubt that the steam was so rarefied by heat as to cause this result.

He also first proposed the mode of generating steam by dispersing water in small portions over a heated surface.

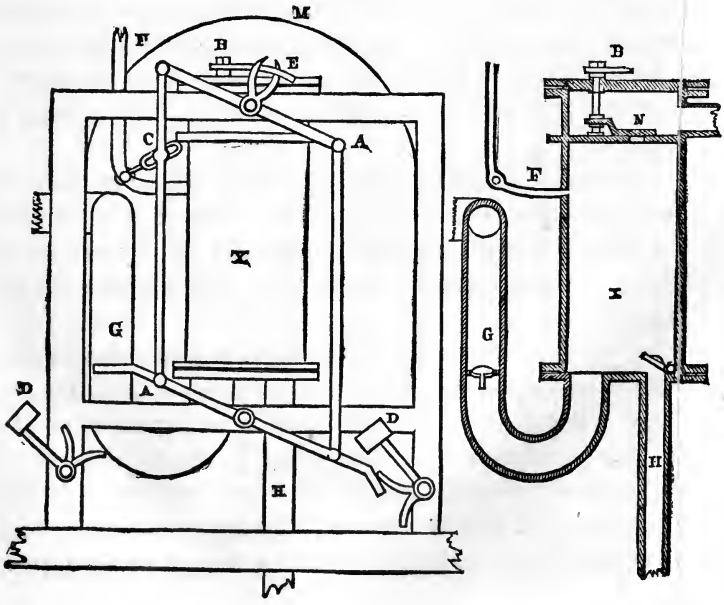
"His apparatus consisted of a cast iron vessel, of the figure of a frustrum of a cone, its diameter at the bottom being four feet, with a semi-globular end of copper, of about four feet and a half in diameter. In the inside a small vessel was inserted, which Payne calls a *disperser*, which vessel had pipes round the sides fixed to it; the bottom rested on a central pin, on which it revolved, so as to spread the water it received from above, through an iron pipe. The end of this pipe passed up through the head, and was enclosed very tightly, but so as to be very easily moved with a circular motion, so that the water might be dispersed or showered round on the sides of the red-hot cone, or ignited vessel, in a very exact manner. From experiment he states that a pot or vessel, of the size and shape here mentioned, will, being kept to a dark red heat, and the water regularly dispersed, convert 6.5 cubic feet of water into steam in an hour. And that by experiments made at Wednesbury and Newcastle-upon-Tyne, 112 pounds of pit coal will, by this method, convert 12 cubic feet of water into steam."

This idea has been revived in the present day by Mr. Howard.

Though machinery had long superseded the necessity of personal attendance for opening and shutting the valves of Newcomen's engine, it appears that nothing of the kind had been applied to Savery's engines. The first self-acting apparatus for that purpose was invented in 1744, by one Gensanne, a Frenchman. Fig. 13 represents this contrivance. X is the receiver; H, a pipe rising from the cistern; G, the eduction pipe; F, the injection pipe; C, lever of injection cock; B, the axis of the steam valve N, which slides horizontally; M, top of boiler; D D, two tumbling bobs, performing the same office as in the atmospheric engines; A A, levers; E, handle of steam valve.

From the manner in which the levers are connected, their simultaneous operation may be easily perceived. Another method is ably described by Smeaton, in the Philosophical Transactions, 1751. It was by a Portuguese, named De Moura, who had sent a model of his invention to the R. Society.

Fig. XIII.



"The engine consists of a receiver, with a steam and an injection-cock. It has a suction and a forcing-pipe, each furnished with a valve and a boiler, which may be of the common globular shape. Having nothing particular in its construction, a description of it will not be necessary: also, the rest of the parts already mentioned being essential to every machine of this kind, a further account of them may be dispensed with. What is peculiar to this engine, is a float within the receiver, composed of a light ball of copper, which is not loose in it, but fastened to the end of an arm made to raise and fall by the float, while the other end of the arm is fastened to an axis; and, consequently, as the float moves up and down, the axis is turned round one way or the other. The axis is made conical, and passes through a conical socket, which last is fixed to the side of the receiver. On one of the ends of the axis, which projects beyond the socket, is fitted a second arm, which is also moved backwards and forwards by the axis as the float rises and falls. By these means, the rising or falling of the surface of the water within the receiver communicates a corresponding motion to the outside, in order to give the proper motions to the rest of the apparatus which regulates the opening and shutting of the steam and injection cocks, and serves the same purpose as the plug frames, &c., in Newcomen's engine."

In 1751, Mr. F. Blake, F.R.S. published a paper on the best proportions for steam engine cylinders, which being one of the earliest theoretical inquiries respecting the proportions of engines, has just claims to our attention. His reasoning is very ingenious.

"It is evident," he says, "from the principles of mechanics, that the contents of the cylinder remaining the same, the quantity of water discharged at each lift will in all cases be equal; and this equality is obtained by only adjusting the distance of the centre of the piston from the fulcrum of the beam. It will be granted also, that the excess of the column of atmosphere above that of water, is equivalent to a weight on the piston,

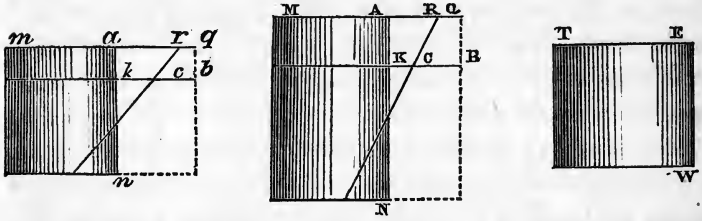
driving it to a depth of about five feet within the cylinder, with an accelerated motion, till the friction and resistance from the uncondensed steam which remains in the cylinder, even after the injection, and which is increased in elasticity while its bounds are diminished, shall equal the accelerative force; and that then again, the piston may be retarded the rest of the way. But independent of friction, we can, notwithstanding this dimunition of force, by the remainder of steam within the cavity of the cylinder, demonstrate the ratio of the velocities and the times of descent of pistons in cylinders of unequal altitudes to be exactly the same as if the resistance were nothing; whence we shall, without difficulty, arrive at some conclusion in this matter. Let M N be the working part of a steam engine cylinder of the usual height, equal in diameter to a shorter one $m\,n$, and the rarefaction in both of them being supposed the same, A Q$=a\,g$ may represent the excess of the atmosphere's weight above the column of water; R Q$=r\,q$, the resistances of the pistons from the remainder of the steam, and A R$=a\,r$, the effective forces. Make $a\,k$: A K : : $a\,n$: A N, and at all similar positions, the resistance $b\,c$ of $m\,n$, and force $k\,c$ on its piston, will be equal to the resistance B C of M N, and force K C on its piston; and (by Newton's Princip. prop. 39,) in the descent of bodies, we have $\sqrt{a\,k\,c\,r}$: $\sqrt{\text{A K C R}}$: : celerity in k : celerity in K. But these areas being evidently as the corresponding parallellograms $k\,q$ and K Q, and these again as their heights, the celerities generated are in the subduplicate ratio of $a\,k$ to A K, as if the resistance had been invariable.

"To apply this to steam engines, if T W be a cylinder of equal content with the cylinder M N, the quantity of water delivered by both will, as observed above, be the same at each lift; but the cylinder T W is no higher than $m\,n$, and their rarefactions are supposed equal. Therefore, by what has been proved with regard to the times, the time of the piston's descent in T W will be to that of the piston's descent in $m\,n$: : $\sqrt{\text{E W}}$: $\sqrt{\text{A N}}$; whence, in any given time, the short cylinder T W will perform more than the larger one M N of equal content,

and that in the ratio of their diameters; for, as $TE^2 \times EW = MA^2 \times AN$, and $EW : AN :: ME^2 : TE^2$; therefore, $\sqrt{EW} : \sqrt{AN} :: MA : TE$. And the friction is diminished with the slowness of the motion, because the periphery of the piston increases in a less ratio than its area.

It will be seen from the above that he is in favour of a short cylinder; and taking the subject as he views it, his conclusions appear tolerably correct. But as Tredgold very justly observes, "The proper question is, What form of the cylinder will enable us to do the most work with the least steam, and not the most work in the least time with a cylinder of a given capacity?"—

FIG. XIV.



In a subsequent paper, he investigated the relation between the power and resistance which gives a maximum effect in a given time when the motion accelerates from rest, both when the force is uniform, and when variable, increasing with the distance.

The importance of economy in the use of fuel in such a machine as the steam engine, is obvious to every one; and amongst the earliest of those who directed their attention to this object, was Mr. Keane Fitzgerald, F.R.S., a gentleman of great scientific attainments. Accordingly, in 1757, we find him proposing to agitate the water in the boiler by a stream of air on the principle of Dr. Hale's plan of evaporation. The projection was a failure; for Fitzgerald had not perceived the difference between forming steam and accelerating evaporization; but its publication caused Hale to consult him respecting using the steam engine to work ventilators in mines.

For this purpose, Fitzgerald contrived a mode of converting

the reciprocatory motion of the Atmospheric Engine into a rotary one, and which was published in the Philosophical Transactions for 1758. The method nearly resembles in principle that contrived by Hulls for his steam boat; but in Fitzgerald's plan, a fly wheel is used for a regulator instead of a weight.

Up to this time, it had been the usual mode to construct the working beam with its axis below the centre of gravity. Fitzgerald pointed out the error, and by altering the place of the axis of the beam of the York Water Works Engine, he considerably increased its efficiency. He also published proposals for erecting corn mills, and "mills of all kinds," to be driven by steam power; but his proposals do not appear to have met with the confidence of the public.

The celebrated mathematician, William Emerson, gives in his Mechanics (1758), a description of the Atmospheric Engine, with the mode of computing its power, as far as statical equilibrium between the power and resistance is concerned. The article is brief but clear. In his Miscellanies, he solves a problem, intended to determine the relation between the power and the resistance when the effect is greatest.

James Brindley, the celebrated engineer, attempted to economize fuel by forming the sides and top of the boiler of wood and the bottom of stone. The fire-place and chimney were made of cast iron and placed inside the boiler, both of them being surrounded by the water as far as possible. By these means, he expected to render more of the heat of the fuel effective, and therefore obtained a patent for the arrangement (1759); but the rapid destruction of the wood by the steam compelled him to abandon his plan, and he afterward had recourse to casing iron boilers with wood. His former plans were not adopted in general practice, being based on erroneous ideas of the quantity of heat and the nature of combustion.

"It may be stated as follows:—In a steam engine, there is given the effective pressure of the atmosphere upon the piston and the length of the stroke, to find the water to be drawn at a

stroke, so that the greatest quantity shall be drawn in a given time, supposing the force uniform, and the arms of the beam of equal length." This solution differs from that of Blake—" in taking the whole time of the ascending and descending strokes into the account, and in not considering the moving power as a gravitating mass of matter." It is, therefore, more strictly applicable to the question, though still not perfectly so, as the space, not the time, should be given.

When we reflect that heat is so general and active an agent in all our operations, mechanical and domestic, it is matter of surprise that its nature, and the laws which govern its generation and transmission, should have been neglected for so long a time, and so little the subject of scientific investigation. Bacon, in his Novum Organon, exemplifies his method of induction by an inquiry into the nature of what he terms, in his quaint but expressive phraseology, the "form of heat." He concludes that "heat appears to be motion," and it is worthy of remark, that his hypothesis is the very same with one of those which, after a lapse of two centuries, still divides the opinion of philosophers. It is still a question whether heat be really matter —a subtile fluid, capable of diffusing itself into bodies or any thing more than motion, vibration or rotation, excited among their particles. The greater part of the facts relating to heat may be explained equally well on both suppositions. From the time of Bacon till 1762, the subject does not appear to have met with much, if any, attention; excepting in some few experiments and contrivances for saving of fuel. At this period, the celebrated Dr. Black made known his experiments, and began to teach publicly his hypothesis of the materiality of heat. To him we owe the first investigation of the combination of heat with bodies in the solid, liquid, and gaseous state. He showed that the heat so combining with them was insensible to the thermometer, and hence he called it *latent* heat.

He found that the quantity of heat required to convert boiling water into steam, exceeded five times the quantity required

to make cold water boil. He also found, that to produce the same degree of temperature in different bodies, different quantities of heat were required. This property of bodies he called capacity for heat; it is now usually termed *specific* heat.

Dr. Black extended his inquiries into the nature and effect of fuel, and taught the principles of managing compound fires. Drs. Irvine and Crawford followed up his inquiries, by making experiments to determine the specific and latent heat of various substances.

John Smeaton, so justly famous for the Eddystone Light-House, and other public works, gave much of his attention to the details of the atmospheric engine, and brought it to nearly as high a degree of perfection as its principles will admit. How far he was acquainted with the discoveries and views of Dr. Black, does not appear; but, if acquainted with them, his mind was not of a cast likely to turn them to account. His ability was principally displayed in improving the construction and proportions of machines already invented, by selecting the best methods known, and making careful experiments on their mode of operation. In 1765, he designed a portable atmospheric engine for the purpose of making trials upon, which seems to have been the first attempt at constructing an engine capable of removal from place to place. A tolerable idea of this machine may be formed from the following description:

"The diameter of the cylinder was 18 inches, its area, in circular inches, 324 inches, and allowing seven pounds to the inch, which such a cylinder, he remarks, would very well carry, we have 2,268 pounds. The motion was communicated from the piston to the pump-rod by a wheel 6.2 in diameter, with a chain instead of a beam. The number of strokes per minute is stated to be ten, of six feet each; hence the effect is $2{,}268 \times 10 \times 6 =$ 136,080 pounds, raised one foot, or four horses' power; he reckoned it equivalent to six horses; and therefore his value of the horse power is 22,680 pounds, raised one foot high per minute, instead of the usual standard of 33,000 pounds."

Respecting fuel, he remarks, it has been found by experience

that a two feet cylinder requires 174 pounds of Newcastle coal per hour; which, reduced in the ratio of the capacity, gives ninety-seven pounds and a half per hour for the eighteen inch cylinder, or a four horse engine, according to the common application of fire; but he had reason to think an engine constructed like his would not require above sixty-five pounds per hour for a four horse engine. The fire-place was of a spherical figure, of cast-iron, and entirely within the boiler; the coals were introduced by a large pipe from the outside of the boiler to the fire-place, and the smoke passed off by a curved pipe, with an iron funnel, to promote a sufficient draught. The ashes fell through a pipe covered by a grate eighteen inches in diameter, the whole being joined to the boiler by proper flanches, and always covered with water. In so short a flue the force of the fire cannot be wholly exhausted within the compass of the boiler, therefore the curved pipe was surrounded by a copper vessel adapted to its shape, into which was brought the feeding water, that it might be raised to a greater degree of heat than it brought immediately from the hot well into the boiler. It is also obvious that, by this arrangement, the coolest part of the water comes in contact with the flue, to take the heat from the smoke before it ascends the chimney. The bars of the grate were cast into a loose ring, and were capable of being taken out, and replaced when occasion required.

He seems to have first introduced the improvements resulting from his experiments early in 1774, and by their application, the expenditure of fuel was reduced about one-third. Several large atmospheric engines were erected under his direction, which, from their general excellence, and the admirable manner in which the boilers are adapted for generating steam, have not been exceeded in later times.

In 1775, he designed and erected the famous Chase-water engine. It has a 72 inch cylinder, with a 9 feet stroke, and is of 108 horse power. The estimated consumption is 1,136 pounds of Newcastle coal per hour, and it was proposed to make nine

strokes per minute, at its full power, to be regulated by the cataract to four and a half strokes per minute. It is particularly deserving of attention, from the able and curious construction of the beam.

In the collection of his papers, purchased by Sir Joseph Banks, is to be found a table of the proper proportions of the parts of different sized engines; indeed, few practical circumstances connected with the atmospheric engine escaped his inquiry. His most important researches are relative to the piston, on which he remarks, "he had found engines calculated to carry a load varying from under five pounds to upwards of ten pounds to the square inch, those lightly loaded being expected to go with the greatest velocity; so that an engine carrying five pounds to the inch, must go with double the velocity of one loaded to ten pounds, the cylinders being of equal area, in order that the effects of the power might be equal." He further adds, that in engines, however, as in other machines, there is a maximum which, without new principles of power, cannot be exceeded—bad proportions of the parts, and bad workmanship, may make an engine fall short, in any degree, of what it should do, but its maximum cannot be exceeded by the most skilful artist. He concludes that any load will do, if the parts be properly proportioned; but, from a long course of very laborious experiments, he had fixed his scale near upon, but somewhat under, eight pounds to the inch, including raising the injection water.

The experience of preceding engineers had induced nearly the same conclusion. In their first engines, Newcomen and his copartners made the load on the piston a little over eight pounds per square inch, but they afterwards diminished it; and before Smeaton's time, the general rule acted upon, in the construction of the best engines, was to load them to about seven pounds on the square inch.

The uses to which he proposed the steam engine should be applied, showed the imperfect state of mechanical sciences at that time. He proposed to construct a steam engine to raise

water; the water to be made use of for turning a water-wheel to draw up coals; also to drive a corn mill by water, which was to be raised by one of Boulton and Watt's engines, erected for the purpose, and we find him using the following reasoning on the subject:

"It is to be apprehended that no motion communicated from the reciprocating beam of an engine can ever act with perfect equality and steadiness in producing a circular motion, like the regular efflux of water in turning a water-wheel; and much of the good effect of a water-mill is well known to depend upon the motion communicated to the mill-stones being perfectly equable and smooth: the least tremour or agitation takes off from the complete performance. Secondly, he says, all the engines he had seen were liable to stoppages, and so suddenly, that in making a single stroke, the machine is capable of passing from nearly its full power and motion to rest; for whenever the steam gets lowered in its heat below a certain degree, for want of renewing of the fire in due time or otherwise, the engine is then incapable of performing its functions. In the raising of water, (a business for which the fire-engine seems peculiarly adapted,) the stoppage of the engine is of no other ill consequence than the loss of so much time; but in the motion of mill-stones grinding corn, such stoppages would have had a peculiarly bad effect."

Watt's new mode of operation, which was now becoming pretty generally public, tended much to reduce the value of Smeaton's improvements, by nearly superseding the use of the atmospheric engine. But, had he done nothing else for mankind, he would be deserving the highest praise for his laborious investigations of the subject; and it must be allowed, that even the wonderful inventions of Watt owed much of their practical efficiency to his employing the admirable modes of construction which Smeaton had applied to the air pump.

We should be acting unjustly, were we to suffer the name of Blakely to pass without notice. In 1776, he obtained a patent for a new mode of constructing Savery's engine, by using two

receivers, one placed over the other, with a pipe of communication between them. To avoid the condensation arising from the contact of the steam and water, he proposed to introduce a stratum of oil on the surface of the water; because oil did not so readily absorb the caloric: thus forming a species of fluid floating piston.

He also proposed the interposition of a body between the steam and the water to prevent their coming in contact. The celebrated Ferguson delivered several lectures on these supposed improvements, and great contentions arose amongst almost all the scientific men of the day as to the practicability of the project; but it proved a complete failure. Indeed, both methods are evidently very inferior to the floating piston of Papin.

His merit consists in his having been the first to propose the use of cylindrical tubes for boilers; an idea which was renovated by Perkins, and which has subsequently been so adventitiously adopted in the construction of locomotive engines. His description of this invention was published in 1774, and in 1793, he published at London a pamphlet, entitled, "A Short Historical Account of the Invention, Theory, and Practice of Fire Machinery," chiefly filled with short notices of his own labours.

We have now arrived at what may be considered the most important and interesting period of our history; the time when the steam engine was improved and remodelled—we may almost say invented—by the genius of Watt.

This truly illustrious man was born in 1736, at Greenock, in Scotland; his father being a respectable merchant, and filling the office of baillie or magistrate of the town, and much esteemed in his narrow sphere as a man of great benevolence. His grandfather and uncle were both respectable mathematicians; the former was a schoolmaster, and the latter is known as the author of "A Survey of the Clyde." From his infancy Watt was of delicate health, to which, perhaps, in a considerable degree, may be traced the retiring and studious habits for which he was so remarkable through life. After going through

the usual elementary course of education, which the excellent grammar schools of that country afford such facilities for acquiring, he was, at the age of sixteen, apprenticed to a mathematical instrument maker, with whom he remained four years.

This occupation, however, differed widely from what is now understood by that term. It included not only the making and repairing the general run of mathematical instruments, but also making and repairing clocks, fishing tackle, all kinds of musical instruments, and acting as a rough cutler. At the age of twenty, he went to London, and placed himself under a regular mathematical instrument maker, with whom he acquired habits of dispatch and order in business; but finding his health decline, he returned to Scotland at the end of a year, intending to settle in Glasgow, and begin business on his own account; but not being a citizen, and the corporation laws of this city restricting all exercise of trade to the burgesses, he would have been compelled to relinquish his intention, had he not fortunately obtained the appointment of mathematical instrument maker to the University. The ancient privileges of this institution secured to him the desired immunity from the restriction; and the professors gave him apartments in the college, in which he lived and carried on his business. The University possessed a philosophical apparatus, together with funds for the support of a professor of natural and mechanical philosophy. Watt was thus early placed in a situation well calculated to excite and develope his peculiar powers; and as far as we can, we shall allow him to give the history of his studies in his own words. "My attention," says he, "was first directed in 1759, to the subject of steam engines by Dr. Robison, then a student in the University of Glasgow, and nearly of my own age. Robison at that time threw out the idea of applying the power of the steam engine to the moving of wheel carriages, and to other purposes; but the scheme was not matured, and was soon abandoned on his going abroad." In 1761–62, Watt made his first experiments with steam of a high pressure, and an apparatus resembling Leupold's engine; but "soon relinquished

the idea of constructing an engine upon this principle, from being sensible it would be liable to some of the objections against Savery's engine from the danger of bursting the boiler, and the difficulty of making the joints tight; and also that a great part of the power of the steam would be lost, because no vacuum was formed to assist the descent of the piston." His attention being taken up by his regular business, he did not make any further experiments till the winter of 1763–64, when, being employed by Professor Anderson to repair a model of Newcomen's engine belonging to the Natural Philosophy class, his thoughts were again turned to the subject. At that period, he informs us, "his knowledge was derived principally from Desaguliers, and partly from Belidor, and he set about repairing the model as a mere mechanician;" but when it was done and set to work, he found the consumption of steam so great, that the quantity wasted must have been in a very large proportion to that used. He at first supposed this arose from the circumstance that brass, the metal of which the cylinder was composed, was too great a conductor of heat. Accordingly, he made some experiments with wooden cylinders soaked in linseed oil and baked to dryness; but he soon found that wooden cylinders would not be sufficiently durable. Besides which, the "steam that was condensed in filling them, still exceeded the proportion of that which was required for engines of larger dimensions. It was also found, that unless the temperature of the cylinder itself were reduced as low as that of the vacuum, it would produce vapour of a temperature sufficient to resist part of the pressure of the atmosphere. All attempts, therefore, to produce a better exhaustion by throwing in a greater quantity of injection water was a waste of steam; for the larger quantities of injection water cooled the cylinder so much, as to require quantities of steam to heat it again, out of proportion to the power gained by having made a more perfect vacuum; and on this account, the old engineers acted wisely in loading the engine with only six or seven pounds weight on each square inch of the piston."

Watt therefore found the engine involved in this dilemma; either much or little condensation water was to be used. If much were used, the vacuum would be perfect, but then the cylinder would be cooled, and would entail an extensive waste of fuel in heating it again. If little were used, a vapour would remain, which would resist the descent of the piston, and rob the atmosphere of a part of its power.

From the small quantity of water in the form of steam which filled the cylinder, and the large quantities of injected water to which this steam communicated heat, he was next led to inquire into the comparative density of steam and water, and what proportion of heat subsisted between them. Of these inquiries, Dr. Ure gives the following interesting account:—"In some conversations with which this great ornament and benefactor of his country honoured me a short period before his death, he described, with delightful *navieté*, the simple and decisive experiments by which he discovered the latent heat of steam. His means and leisure not then permitting an expensive and complex apparatus, he used apothecaries' phials; with these he ascertained the two main facts, that a cubic inch of water would form about a cubic foot of ordinary steam; and that the condensation of that quantity of steam would heat six cubic inches of water from the atmospheric temperature to the boiling point. Hence he saw that six times the difference of temperature, or fully 800 degrees of heat had been employed in giving elasticity to steam; and which must all be subtracted before a complete vacuum could be obtained under the piston of a steam engine. Struck with the singularity of this circumstance, "I mentioned it," says Watt, "to my friend, Dr. Black, who then explained to me his doctrine of latent heat, which he had taught for some time before this period (summer 1764); but having myself been occupied with pursuits of business, if I had heard of it, I had not attended to it, when I thus stumbled upon one of the material facts upon which that beautiful theory is founded."

On reflecting further, it appeared to him, that in order to obtain the greatest power from the steam, the cylinder should

always be kept as hot as the steam which entered it; and that when the steam was condensed, the water of condensation and the water of injection should be cooled to 100 degrees of Fahrenheit, or lower if possible.

Watt now gave his whole mind to the consideration of a method of "condensing the steam without cooling the cylinder." Various were the means contemplated by him to effect this object, when early in the year 1765, the thought struck him, "*that if a communication were opened between a cylinder containing steam, and another vessel which was exhausted of air and other fluids, the steam, as an expansible fluid, would immediately rush into the empty vessel, and continue to do so until it had established an equilibrium; and if that vessel were kept very cool, by some injection or otherwise, more steam would continue to enter until the whole was condensed.*"

This happy conception was the first step in that brilliant career which has immortalized the name of Watt, and has spread his fame to the very skirts of civilization. But a difficulty presented itself. How were the injection water and the air entering with it, and also that produced by the condensation of the steam to be disposed of? The water indeed could be allowed to run off through a syphon, but the air was not removed. At last it occurred to him that a pump would draw off both air and water, and preserve a perfect vacuum in the condenser. It was easy to see how this pump could be worked by the machine itself. This constituted the second great step in the invention.

The piston had always heretofore been kept air-tight by water above it. Watt perceived, that in this new method, if any of the water entered the partially exhausted cylinder, which was now kept at a heat of 212°, it would boil, and by generating vapour, prevent the production of a vacuum, besides cooling the cylinder by its evaporation during the descent of the piston. To obviate this, he proposed to "lubricate the sides and keep the piston air-tight by employing wax or tallow."

It next occurred to Watt, that the mouth of the cylinder being

open, the air which entered to act on the piston would cool the cylinder and condense some steam on again filling it. He therefore proposed "to put an air-tight cover on the cylinder, with a hole and shutting box for the piston to slide through, and to admit steam above the piston, to act upon it instead of the atmosphere."

This was the third step in this great invention, and one which totally changed the character of the machine. It now became really a *steam-engine;* for the pressure above the piston was the elastic force of steam, and the vacuum below it was produced by the condensation of steam; so that steam was used both directly and indirectly as the moving power; whereas, hitherto atmospheric pressure had been the moving power—steam having been used merely as a means of producing a vacuum.—Another source of the loss of heat—the cooling of the cylinder externally, by the air of the atmosphere—he at first proposed to remedy, by casing the cylinder in wood or some other substance, which would conduct heat slowly; but subsequently, he enclosed one cylinder within another, leaving a space between them, which he kept constantly filled with steam. Thus the inner cylinder was kept constantly at the temperature of the steam which surrounded it. When once the idea of separate condensation struck him, all these improvements he states "followed in quick succession; so that in the course of one or two days, his invention was so complete that he proceeded to submit it to the test of experiment."

His experiments were made at first with a small apparatus, and finally with a working model having a nine inch cylinder. The results were most satisfactory. He saw that he had discovered a remedy for the defects of the atmospheric engine. The steam was no longer wasted, and a more perfect vacuum was produced. He had computed that the heat wasted was three times greater than that usefully employed; and as, by his improvements, nearly all waste was prevented, he contemplated and afterwards actually effected a saving of three-fourths of the fuel.

Although fully sensible of the value of his discovery, he proceeded no further in it at this time, but "devoted himself, for upwards of three years longer, to pursuits far beneath the powers of his mind." Indifferent health, the press of business, or the want of funds, prevented him from securing his invention by patent; and at no period of his life was he possessed of the self-confidence necessary to bring his discoveries before those whose patronage or assistance might enable him to carry his designs into execution.

On the occasion of his marriage, in 1764, he had left his apartments in the College, and commenced the practice of land-surveying, by the advice and with the occasional assistance of his uncle. He soon got into respectable practice; and, in the course of his employment, he formed an acquaintance with Dr. Roebuck, an English gentleman, the founder of the celebrated Carron iron-works. Possessed of liberal education, considerable scientific attainments, unbounded enterprize, and some fortune, here was a man well qualified to appreciate the merit of Watt's improvement; and by his assistance, Watt was enabled to erect an experimental engine, which was tried at a coal-mine, at Kinneil. This engine had an eighteen inch cylinder, and was successively altered and improved till it was brought to considerable perfection. During its erection, Watt, in connection with Roebuck, applied for his first patent, which was enrolled in April, 1769, and was for his "Methods of lessening the consumption of Steam, and, consequently, of Fuel, in his Fire Engine." The specification was not illustrated with figures. It runs thus:

"First. That vessel in which the powers of steam are to be employed to work the engine, which is called the cylinder in common fire-engines, and which I call the steam vessel, must, during the whole time the engine is at work, be kept as hot as the steam that enters it; first, by enclosing it in a case of wood, or any other materials that transmit heat slowly; secondly, by surrounding it with steam, or other heated bodies; and thirdly, by suffering neither water, nor any other substance

colder than steam, to enter or touch it during that time. Secondly; in engines that are to be worked wholly or partially by condensation of steam, the steam is to be condensed in vessels distinct from the steam-vessels or cylinders, although occasionally communicating with them: these vessels I call condensers; and whilst the engines are working, these condensers ought at least to be kept as cold as the air in the engines, by the application of water or other cold bodies. Thirdly; whatever air or other elastic vapour is not condensed by the cold of the condenser, and may impede the working of the engine, is to be drawn out of the steam-vessels or condensers by means of pumps, wrought by the engines themselves or otherwise. Fourthly; I intend, in many cases, to employ the expansive force (pressure) of steam to press on the pistons, or whatever may be used instead of them, in the same manner as the pressure of the atmosphere is now employed in common fire-engines. In cases where cold water cannot be had in plenty, the engines may be wrought with this force of steam only, by discharging the steam into the open air as soon as it has done its office. Fifthly; where motions round an axis are required, I make the steam-vessels in form of hollow rings or circular channels, with proper inlets and outlets for the steam, mounted on horizontal axles, like the wheels of a water-mill; within them are placed a number of valves that suffer any body to go round the channel in one direction only. In these steam-vessels are placed weights so fitted to them as entirely to fill up a part or portion of their channels, yet rendered capable of moving freely in them by the means hereinafter mentioned or specified.

"When the steam is admitted in these engines between these weights and the valves, it acts equally on both, so as to raise the weight to one side of the wheel, and by the reaction on the valves successively, to give a circular motion to the wheel, the valves opening in the direction in which the weights are pressed, but not in the contrary; as the steam vessel moves round, it is supplied with steam from the boiler; and that which has per-

formed its office may either be discharged by means of condensers or into the open air. Sixthly, I intend in some places to apply a degree of cold not capable of reducing the steam to water, but of contracting it considerably, so that the engines shall be worked by the alternate expansion and contraction of the steam. Lastly, instead of using water to render the piston and other parts of the engines air and steam tight, I employ oils, wax, resinous bodies, fat of animals, quicksilver and other metals, in their fluid state.

"Be it remembered, that the said James Watt does not intend that any thing in the fourth article shall be understood to extend to any engine where the water to be raised enters the steam vessel itself, or any vessel having an open communication with it."

After erecting the engine at Kinneil, Watt had begun to make arrangements to manufacture his engines on a considerable scale, when his partner, Roebuck, became involved in embarrassments by the failure of some mining speculations, so as to be unable to make the necessary pecuniary advances. Harassed and disappointed, Watt was about to relinquish the further prosecution of his plans, when Mr. Bolton, a gentleman who had established a factory at Birmingham, made proposals to purchase Dr. Roebuck's share in the patent, which were accepted by that gentleman; and, in 1773, Watt entered into partnership with Bolton.

Watt now removed to Birmingham, and a brighter prospect opened; his new colleague was a man of affluence, and of great personal influence, "and to a most generous and ardent mind, he added an uncommon spirit for undertaking what was great and difficult." "Mr. Watt," continues Professor Playfair, "was studious and reserved, keeping aloof from the world; while Mr. Bolton was a man of address, delighting in society, active, and mixing with people of all ranks with great freedom, and without ceremony. Had Mr. Watt searched all Europe, he could not have found another person fitted to bring his invention before the public in a manner worthy of its merit and

importance ; and although of most opposite habits, it fortunately so happened that no two men ever more cordially agreed in their intercourse with each other." Finding that the period of the patent must expire before they could be reimbursed, even the necessary expenses attending the arrangements for manufacturing the engines, with the advice and influence of his friends, application was made to Parliament for an extension of the term, which, after some opposition, was granted for twenty-five years from the date of his application (1775), so that his exclusive privilege should expire in 1800. An engine was now erected as a specimen for the examination of mining speculators, and the engines began to come into demand. The principle adopted by Watt, in granting licenses to use his engines, is remarkable for its fairness and liberality. It was, that he should receive one-third part of the saving of coals, which was made by his engines, when compared with the atmospheric engines hitherto used.

Notwithstanding the manifest superiority of these engines over the old atmospheric engines, yet such was the influence of prejudice, and the dislike of what is new, that Watt found great difficulties in getting them into general use. The increased first cost also operated against them. In order to induce proprietors of mines who were unable or unwilling to be at the expense of new engines, Bolton and Watt at first took the old atmospheric engines in part payment, at a price far above their real value, and gave credit for the remainder until advantage should be experienced ; and they even erected some engines, on and at their own expense, to be paid provided they answered the expectations which they, as manufacturers, held out were obtained by their adoption. And it appears that they actually expended the sum of forty-three thousand pounds before they began to receive any remuneration.

In the course of Watt's experiments, even before he procured his patent, he had been struck with the remarkable fact of what is now called the expansion of steam when admitted into a vacuum. This power was first partially adopted by him to

equalize the motion of the piston, by shutting off the steam when the piston had gone through one-third of its stroke, leaving the other two-thirds to be completed by the expansive force alone. It was subsequently introduced as a means of saving steam in an engine at Soho manufactory, in 1776, and in 1778, at Shadwell Water Works; and afterwards particularly described in his specification of a patent, in 1782.

In both the atmospheric engine and the improved steam engine of Watt, the power of the steam acted only during the descent of the piston; but during the ascent its agency was suspended. Besides this, the weights or counterpoises, which caused the ascent of the piston, acted against the power in the descent. Again, being of an intermitting nature, the power acted only in one direction. When applied merely to pumping, this suspension of impulse was no defect; but when it was required to move machinery, it was a great drawback on its usefulness. Watt's next step towards the perfection of the machine was to obviate this inconvenience, and he accomplished it by a very slight extension of his first idea. He had introduced steam acting against a piston to force it downwards; he now formed a communication between both sides of the piston and the boiler, and also with the condenser, and made the steam act to press the piston upwards as well as downwards. This improvement constituted what is called the double acting steam engine; and the mechanism was now, as far as the principle went, perfect; and it was freed, for the first time, from the enormous dead weight of counterpoise.

Even after the motion of the piston was equalized by shutting off the steam sooner or later from the cylinder, another source of irregularity presented itself in the varying quantity of steam, which in different states of the fire was admitted into the cylinders. To adjust this by means of the throttle valve, and to make this valve a self-acting one by the application of the governor, was the next successful effort of Watt's surprising ingenuity.

It will be seen that Watt's specification contains the first

idea of a rotary steam engine ; but the steam wheel not answering, he directed his attention to converting the reciprocating motion into a rotary. The contrivances of Hulls and Fitzgerald for this purpose have been already described. Patents for similiar ones had been taken out by Stewart, in 1769, and Washborough, in 1778. "Among the many schemes," says Watt, "which passed through my mind, none appeared so likely to answer the purpose as the application of a crank in the manner of a common turning lathe (an invention of great merit), of which the humble inventor, and even its era are unknown."

On trial, it succeeded beyond his most sanguine expectations ; but being communicated to Washborough by the workman employed to make the model, he forestalled the invention by taking out a patent in 1781, under the name of Steed. The fact was acknowledged by both the workman and Washborough's chief engineer; the latter, however, excused himself by saying, that the same idea had occurred to him, and that he had even made a model previously. "This," Watt says with great candour, "might be a fact, as the application of it to a single crank was sufficiently obvious ; and, in these circumstances, I thought it better to accomplish the same end by other means, than to enter into litigation, and by demolishing the patent, to lay the matter open to everybody." Accordingly, we find him procuring a patent for five different methods of producing rotary motion, among which was the sun and planet wheel motion, which he used until the expiration of Steed's patent, when the crank was resumed. In 1782, he obtained another patent for five different methods of applying steam.

First, for an expansive steam engine, with six different contrivances for equalizing the power ; secondly, the double power steam engine, in which the steam is alternately applied to press on each side of the piston, while a vacuum is formed on the other ; thirdly, a new compound engine, or method of connecting together the cylinders and condensers of two or more distinct engines, so as to make the steam, which had been employed to press on the piston of the first, act expansively upon the piston

of the second, &c.; and thus derive an additional power to act either alternately or conjointly with that of the first cylinder; fourthly, the application of toothed racks and sectors to the end of the piston or pump rods, and to the arches of the working beams instead of chains; fifthly, a new reciprocating semi-rotative engine or steam wheel.

His next invention was the parallel motion, of which it may truly be said that it is difficult to find any contrivance more scientifically beautiful. This he secured by patent, in 1784 and in the following year, he obtained a patent for a new smoke consuming furnace for the governor, steam guage, condenser guage, and indicator; these completed the mechanism of the double engine.

The expansive power of steam was investigated by Watt on scientific principles, and he explained his theory with great clearness. In the latter part of his life, he devoted a considerable portion of his time and attention to the study of chemistry and its application to the arts. He wrote some historical notices of his own inventions, and corrected a few misstatements in Robison's article on steam, in his "Mechanical Philosophy," and added some notes, in which he gives an account of his experiments on latent heat and the elastic force of steam.

We have already noticed the important services of Bolton in the introduction and advancement of the steam engine, and on reverting to the subject, find we cannot conclude this part of our sketch better than by quoting the Baron Dupin. "Watt's engine was, when invented by him, but an ingenious speculation, when Bolton, with as much courage as foresight, dedicated his whole fortune to its success. Men who devote themselves entirely to the improvement of industry, will feel in all their force the services that Bolton has rendered to the arts and mechanical sciences, by freeing the genius of Watt from a crowd of extraneous difficulties, which would have consumed those days that were far better devoted to the improvement of the useful arts.

In a memoir published at Basle, in 1769, T. H. Zigler de-

scribes a curious apparatus, invented by him for trying the elastic force of different vapours, and gives the result of his experiments; but they are unfortunately useless, from his having neglected to free his apparatus from atmospheric air.

In 1781, Jonathan Hornblower, of Penrhyn, Cornwall, obtained a patent for a very peculiar and ingenious method of applying steam power. It consisted in having two cylinders, so connected together, that the steam, after acting in the first cylinder the same as in a high pressure engine, was permitted to expand itself in the other and operate a second time, and from thence it passed to a separate condensing vessel; for if a partial vacuum be formed on one side of a piston while steam is confined on the other, the steam will expand and move the piston till an equilibrium of force is obtained, and the power communicated during this motion is an addition to the ordinary pressure.

The effect of this arrangement would be similar to that produced by Watt's plan of cutting off the steam before the piston has completed its stroke; but the operation would be more equable, and as strong steam can be employed with less risk in a small than in a large cylinder, this mode of construction would be of decided advantage in large engines; it is, however, difficult to make the two cylinders act in such harmony that one of them shall not retard the other.

The action of the valves and pumps did not differ in principle from that of Bolton and Watt's engines, and the mode of condensation in a separate vessel being clearly an infringement of the patent, Hornblower could make no use of his invention. Two very ingenious contrivances to obtain rotary motion by the direct action of steam were also patented by Hornblower, in the years 1798 and 1805 respectively. The first was exceedingly complicated, but the second is pronounced by Tredgold to be one of the simplest combinations ever proposed for that purpose. We copy his description.

It consists of four vanes revolving in a cylinder around its axis. The vanes are like those of a smoke-jack, but of thick-

ness sufficient to form a groove in their edges, to hold stuffing, for the purpose of making them steam-tight in their action. They are mounted on an arbour, which has a hollow nave in the middle. Into this nave the tails of the vanes are inserted, and each opposite vane affected alike by having a firm connection with one another; so that if the angle of one of the vanes with the arbour be altered, the opposite one will be altered also, and the opposite ones are set at right angles to each other; so that when a vane is flatly opposed to the steam, the opposite vane will present its edge to it, and thus they are continually doing in their rotation on their common arbour; so that the steam acts against the vane on its face for about a quarter of a circle, or ninety degrees, in the cylinder where it is destined to act; and as soon as it has gone through the quarter of the circle, it instantly turns its edge to the steam, while at the same instant another vane has entered the working part of the revolution, and the rotation proceeds without interruption. This engine was to be furnished with the condenser and discharging pump of Watt, but Hornblower added what he considered an improved method of discharging the air from the condenser."

A series of experiments on the elastic force of steam from 32 to 212, and on the vapor of alcohol, were made by M. Achard, and published in 1782. He took notice that the temperature of alcoholic vapor is about thirty-five degrees lower than that of steam, when the elastic force of the two vapours is equal, but that the difference of temperature is not constant; it seems to vary as the elastic force is greater or less.

It does not appear that Jonathan Hulls ever subjected his plans for steam navigation to actual experiment. The first practical application of the steam engine to that purpose seems to have been by a French Nobleman, the Marquis de Jouffray, in 1781, when he made some experiments, on the river Soane, at Lyons, with a boat 140 feet long, 15 feet wide, and having a draught of 3.2 feet. The boat is said to have been in use fifteen months. We are ignorant of the details and arrangement of the mechanism of this vessel, and equally so of the circumstance which occasioned the scheme to be abandoned.

A Mr. William Symington, of Falkirk, having made a model for a steam carriage of his invention, it was seen by Mr. Miller, of Dalswinton. This gentleman had for some time contemplated the possibility of employing steam for propelling boats, and he engaged Mr. Symington to make a small engine to propel a double boat on Dalswinton Loch. The engine was made, fitted to the boat, and tried, on the loch, in the autumn of 1788, and worked so well, that Mr. Miller determined on repeating the experiment on a larger scale. Accordingly, he commissioned Mr. Symington to purchase a gabart or large boat, at Carron, and to fit up another engine for the purpose. In the summer of 1789, the trial of his second boat was made, on the Forth and Clyde canal, having on board Messrs. Miller, Stanton, Taylor, and other persons; but Mr. Miller, having shewn the practicability of his idea, from some unknown cause or other, appears to have relinquished the subject entirely afterwards.

About this time, the Chevalier Bettancourt entered on a course of experiments on the force of the vapours of water and alcohol, at different temperatures. They were not sufficiently precise to develope the laws of vapour; but they were more accurate than any which had been before published. Being employed by the Spanish Government to collect models of the best Hydraulic Machines, he made a model of the double-acting engine, with a new mode of forming the valves of his own invention, which model, according to Proney, was made from merely seeing the exterior of a double-acting engine when at work.

The most extensive treatise on the steam engine, in the French language, is that of M. Proney, in his Architecture Hydraulique. The reader will be able to form a tolerable idea of the nature and merit of the work from the following description, which we have taken from Tredgold:

"M. Proney begins with the properties of caloric, and the tables of Bettancourt on the force of vapour; and from the latter, constructs an empirical formula for calculating the force of vapour at different temperatures. These are not a little com-

plex, considering their want of conformity with experiment. He then proceeds to the description of engines as then constructed, and their parts, which are illustrated by plates, having figures on a large scale. When he arrives at the parallel motion, the nature of the curve described by the extremity of the piston rod is very fully investigated with tables, to shew its variation from a straight line for a given range in the curve. It is followed by the proposal of a method for determining the diameter of the steam-cylinder, which is little better than telling the artist to guess at it, and correct his guess by an intricate formula. The part on the steam engine terminates with a calculation of the effect produced by a given quantity of fuel, where the time of combustion is certainly erroneously introduced.

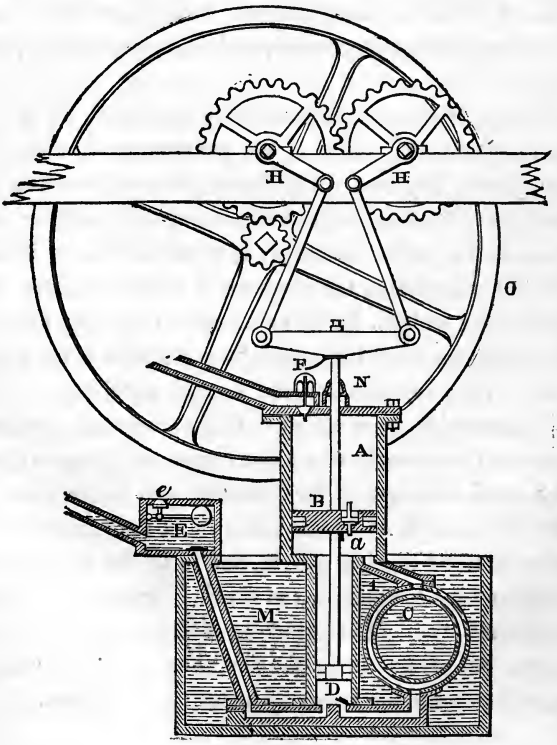
His formulæ for the expansive forces of elastic fluids and vapours, at different temperatures, have been shewn to be based on inaccurate experiments, and are, consequently, wholly useless.

In 1795, a work on mill-machinery appeared, by Mr. John Banks, in which he treats of the maximum of useful effect in Atmospheric Engines. His investigation differs from those of Blake and Emerson, in his considering the space or length of the stroke the given quantity; and his solution is incorrect, owing to his considering the pressure of the atmosphere merely as a gravitating weight. In his solutions, he includes the weight of the moving parts of the engine, and he adds some practical formulæ, with examples for the statical equilibrium of machines employed to raise water. In a subsequent publication, he treats on the strength of engine beams, and gives a description of a rarefaction-guage for cylinders and condensers. His rules for the strength of beams are, to find the relation between the pressure and breaking weight, and to let the weight exceed the pressure by six, eight, or ten times. These rules apply to both wood and iron. The principle of his guage is that of the barometer, but differs from the common condenser-guage in having a cistern for the mercury instead of a syphon.

In 1797, the Reverend Edward Cartwright, a gentleman well known for other mechanical inventions, obtained a patent for the construction of a single-acting engine, which is represented in figure 15.

A is the cylinder; B, the piston; I, the pipe which conducts the steam to C, the condenser, where it passes between the inner and outer cylinder into the pump D, which returns the condensed fluid back into the boiler, through E, the air-box, with *e*, its valve. As the pipe from the pump, through which the condensed fluid is returned into the boiler, passes through the air-box, what air or elastic vapour may be mixed with the fluid rises in the box till the ball that keeps the valve *e* shut falls and suffers it to escape. F is the steam-valve; *a*, the piston-valve; H H, two cranks, upon whose axles are two

FIG. XV.



equal wheels working in each other, for the purpose of giving a rectilinear direction to the piston-rod; and M is the cistern that contains the condensing water. O is the fly-wheel, for regulating the motion.

This simple but ingenuous and elegant machine merits our attention on more grounds than one. First, the steam is condensed, without a jet, by the application of cold water to the outside of the condenser. To effect this, two cylinders are placed one within the other; the water of the cold cistern flowing through the inner cylinder and surrounding the outer one. The narrow space between the two cylinders forms the condenser, and thus a very thin body of steam is exposed to a large cooling service. Second, the communication between the cylinder and condenser is constantly open, so that the condensation is continuous, whether the piston be ascending or descending. Third, the piston, instead of being packed in the ordinary way, was made solely of metal, and so constructed as to be expansive. It consisted of two plates, between which metallic rings, cut into segments, were placed; these rings being forced outwardly against the surface of the cylinder by springs, the piston adapts itself to any inequality which may arise in its form, and fits it more accurately the longer it is worked, so that the machine improves as it wears. The piston-rod works in a metallic box, constructed in a similar manner. Fourth, three valves only are employed—two in the cylinder for the admission and emission of steam, and one to allow the escape of air from the air-box, and these are as nearly self-acting as can well be conceived.

A chief object with Cartwright, in this arrangement, was the substitution of the vapour of ardent spirits for that of water to work the engine. Alcohol boils at lower heats than water, and it was then supposed that a sufficient power might be obtained from it with a saving of half the fuel. Now, one of the peculiarities of this mode of construction is, that the liquid used to produce the steam circulates through the machine without admixture with any other fluid, and with little or no waste; so

that the boiler requires no more feeding than can be supplied from the air-box. Under these circumstances, the use of alcohol would be attended with no expense after the first supply. He further suggested that the engine might be used as a still, as well as a mechanical power, in which case the whole of the fuel would be saved; but how this was to be done, has not been explained.

Though both theory and practice join to assure us that this engine cannot be advantageously employed, we are struck with admiration at the elegant ingenuity which distinguishes the design. The highest constructive ability—that of simplicity—is displayed throughout the whole; and we must not omit to observe that, to Cartwright we are most undoubtedly indebted for the invention of the metallic piston; the other parts of his machine were only new in their adaptation and arrangement, but this was entirely new in principle, and has proved as practically useful as the idea was theoretically beautiful.

A contrivance for a rotary machine is included in the same patent; but independently of the loss of effect necessarily attendant on the action of steam on a rotary piston, its construction, though apparently simple, is, in reality, involved in difficulties.

A work on the Atmospheric Engine was published at Sheffield, in 1797, by John Curr, illustrated by plates, showing the parts of engines, on a large scale. It treats on the proportions of the parts, and gives general directions for their construction, in brief technical terms; but it contains no general description of the engine, and no reasons are assigned for any of the proportions; but, in treating of the pressure on the piston, he says, that when the pressure was increased from "seven to eight and a half lbs. per square inch, the engine did less, and also when reduced to 6.1 lbs. it did somewhat less;" and he does not recommend a greater load than six and a quarter or six and a half lbs. The engine had a sixty-one inch cylinder, and made twelve strokes, of eight feet and a half inch, per minute. The consumption of coals was ten hundred weight of small coal, or

slack, per hour. The power of the engine would be nearly equal to fifty-four horses' power; and as the ratio of coal to slack is about as three to four, it is equivalent to about 840 lbs. of coal per hour: and, at this ratio, 1 lb. of slack raises 97,000 lbs. of water one foot high, and 1 lb. of coals, 130,000 lbs. one foot high.

In Nicholson's Philosophical Journal for 1797, we find a description of an engine, erected in 1793, by a Mr. Kier. It was on Savery's principle, and acted wholly by condensation.

"The steam-vessel being raised somewhat above the height to which the water was to be raised, it had a provision for letting in a small portion of air between the steam and the water, and the construction was exceedingly simple and judicious. The boiler was seven feet long, five feet deep, and five feet wide; and it consumed six bushels (522 lbs.) of good coal in twelve hours, in its best state, and seven in its worst state. Under these circumstances, it made ten strokes per minute, and raised seventy cubic feet of water twenty feet high in a minute. According to this statement, in the best state of the engine, 87 lbs. of coal were consumed in two hours, or 120 minutes, and 1,400 cubic feet of water raised one foot high per minute; or, $1,400 \times 120 = 168,000$ cubic feet by 87 lbs. of coal; which, multiplied by $62\frac{1}{2}$ lbs., the weight of a cubic foot of water, and divided by 87, gives 120,000 lbs. for the load, raised one foot by one lb. of coal; which is about one half the effect produced by an engine with a piston and Watt's condenser, and less than the effect of the common atmospheric engine as used for the coal mines."

In this year, John Nuncarrow also proposed an improvement of Savery's engine, by adding a separate condenser, giving motion to a water-wheel by a fall obtained by the power of steam. His construction certainly appears to possess considerable advantages over the original, but at the same time presents difficulties which would effectually prevent its being carried into effect.

Mr. Murray, of the firm, Fenton, Murray & Wood, of Leeds,

did much in improving many parts of the steam engine, and obtained several patents for his improvements. Some of his methods, it appears, had been previously made use of by Bolton and Watt, but till Murray took out his patents, they were not publicly recorded. In his first patent (1799) for "saving Fuel and lessening the expense of Engines," "he proposed to place a small cylinder, with a piston on the top of the boiler, connected to a rack, by means of which the force of steam within the boiler opens or closes the damper fixed on an axis in the chimney; thus increasing or decreasing the draught of the fires, so as to keep up a regular degree of elastic force in the steam. Mr. Murray also thought some advantage would be gained by placing the steam cylinder in a horizontal instead of a vertical position, with a view of rendering the engine more compact than the usual construction. He also adopted a new method of converting the reciprocating motion of the piston to a rotary one of equal power, by means of the property of the rolling circle, and showed how to fix the wheels for producing motion alternately, in perpendicular and horizontal directions. His next patent, taken out in 1801, was for six different objects.

First, for a method of constructing the air-pump; second, for a method of packing stuffing-boxes, &c., by bringing the moveable parts of each in immediate contact, which prevent the piston-rod receiving any oblique pressure, by the lid being screwed down more on one side than the other. The third and fourth methods relate to the construction and motion of the valves. The fifth was a method of connecting the piston-rod to the parallel motion; and the last, for the construction of fire-places, by which the smoke arising from the fire was to be consumed. In most of these, however, he had been anticipated in practice.

In 1802, he obtained a third patent for a portable engine, which patent, however, was repealed in the following year, at the instance of Bolton and Watt, as it included some of their methods. Bolton and Watt's portable engine was first constructed in 1806.

Mr. Murdock, of Redruth, Cornwall, partner in the firm of Bolton and Watt, and well known as the inventor of gas-lighting, made several important improvements in constructing cylinders and working the valves. His patent was taken out in 1799. These improvements consist of a more equable mode of boring the cylinders and pumps, by means of an endless screw and toothed-wheel.

"Casting the steam-cases of one entire piece, to which the cover and bottom of the working cylinder are to be attached." He also proposed to cast the cylinder and steam-case in one piece, of considerable thickness, and bore a cylinder interstice between the steam-case and steam-vessel, leaving the two cylinders attached at one end, and to close the other by a ring of metal. Another improvement included in the patent was, a plan for simplifying the construction of the steam-valves, or regulators, of the double engine, by connecting together the upper and lower valves, so as to work with one rod or spindle. The tube which connects them, being hollow, serves as an eduction pipe to the upper end of the cylinder, and a saving of two valves is effected; and lastly, he adds a scheme for a rotary engine, consisting of two toothed-wheels, working in an air-tight vessel, which, he imagined, would work with considerable power.

The successful application of the steam engine to draining the Cornish Mines was greatly creditable to the skillful superintendence, the activity, and the integrity of Murdock, and the resources he displayed in overcoming the various difficulties which presented themselves. Many of the perfections of the double engine are the result of his contrivances; in particular, his mode of opening the valves added much to its neatness and simplicity.

Amongst those who have written on the principles and construction of the steam engine, Dr. John Robison possessed the rare quality of being able judiciously to combine theoretical and practical information, joined to a facility and clearness of expression, which renders his work invaluable to the inquirer. He bestowed much attention on the subject, and his close inti-

macy with so liberal a friend of science as Watt, gave him access to a quantity of data which he was able to make use of to the best advantage. He commences with an article on the physical properties of steam, in which the phenomena of boiling, and the effect of pressure in altering the temperature necessary to produce that action, with the popular doctrine of latent heat, are fully, though rather diffusely, stated. A series of experiments on the elastic force of the steam of water and the vapour of alcohol, are given; but these, unfortunately, are not sufficiently accurate: and, in consequence, the rule for the elastic force of steam which he derives from them, and gives as "sufficiently exact for practical purposes," is far from being so, and its adoption has tended to mislead several engineers in their attempts at improving the engine. Independent of this, however, the article is replete with useful information, and may be pronounced the best treatise on the power of steam which had at that time appeared.

This article is followed by a historical account of the steam engine and its principal inventors, with detailed descriptions of their various engines, blended with much valuable theoretical discussion, though slightly open to the charge of wanting systematic arrangement. His descriptions are full and particular, and must have been highly useful to all those who were at that time engaged in constructing the steam engine, or investigating its theory. In this portion of his work, some think that his personal feelings, as a friend of Watt, joined to national prejudices, have prevented him from treating the claims of Papin with sufficient respect; but in all other cases he may be pronounced strictly impartial.

His general reputation and ability, as a writer on mixed mechanical sciences, contributed much to the beneficial effects produced by his articles on the steam engine; and it was no small advantage to the practical man to have "the scattered knowledge on the subject collected with so much skill, and treated with so much clearness and good taste."

Bossut's "Speculations on the best Velocity for Atmospheric

Engines" were reprinted by Robison, with additions; as also Watt's "Mode of Computing the Pressure on the Piston of the Expansive Engine." These works, however, are not calculated to be of much use to the mechanic.

In 1800, the Messrs. Robertson, of Glasgow, contrived a new mode of building boiler fire-places. It is on the same principle as those constructed by Watt, but more convenient in practice. They also invented an apparatus for using the steam which escapes by the sides of the piston as part of the effective power; but the complexity and expense was so great, compared with the small increase of power gained, as to render the contrivance of little use.

In 1801, a patent was obtained by Joseph Bramah, for various improvements in construction; the principal of which was a variation in the form, and a new mode of applying the four-way cock. The objection to this cock as commonly worked, was its inequality of wear, which allows the steam to escape, and causes a loss of power. Instead of turning it backwards and forwards in the usual way, Bramah made it to revolve continually in the same direction. The same effect is produced; but this mode of action renders the wear of the cock more equable, and consequently adds much to its durability.

He also adjusted the movements, so as to give, at the proper time, as instantaneous and free a passage to the cylinder and condenser as possible, and formed the apertures, so that the cone might be pressed equally into its seat by the force of the steam.

In the same year, a Mr. Thomas Fenwick published a series of tables for the proportions of the cylinders of atmospheric engines to produce given effects.

He infers from some experiments, that the whole friction of the atmospheric engine is about four pounds per square inch on the area of the piston; and on account of the frequent bad effects attending designing an engine with too small an allowance for excess above its ordinary work, he makes his computations at five and a half lbs. effective power for each square inch of piston.

Having had considerable experience in the management of coal works near Newcastle, he had a good opportunity of knowing what would best answer in practice.

A later edition contains "tables for an improved atmospheric engine with a separate condenser, in which the ratio of the effect is as 17 : 10, when the same sized cylinder is used."

The saving of fuel at coal mines is not a matter of much importance, and therefore does not enter into his calculations. To a coal owner, an engine which is simple and efficient in its operations, and which can be erected at a moderate cost, is of more value than one which being of finer construction requires a greater outlay.

Mr. William Symington, already mentioned, as having constructed the engines for Miller's experiments on steam navigation, had not altogether abandoned the project. Accordingly, having commenced business at Falkirk, we find him, in 1801, building another experimental steam boat, under the encouragement of Thomas Lord Dundas, of Kerse, who wished to introduce steam power on the Forth and Clyde Canal, in place of horse power. Experiments on a large scale were instituted at a cost of nearly $15,000, and in 1802, the boat was completed. It was a tow-boat, with a cylinder twenty-two inches in diameter, and a four feet stroke. It proved to be well adapted for the intended purpose ; but the use of it was interdicted by the Canal Company, from an idea that it destroyed the banks. A complete model of this boat, with a set of ice-breakers attached, is preserved in London, at the rooms of the Royal Institution.

Whilst the investigation of the qualities of steam was confined to its use for mechanical purposes, few interested themselves in the inquiry, and its progress was comparatively slow ; but as a knowledge of the nature and properties of that and other vapours became important in chemistry, meteorology, and other branches of natural philosophy, the subject obtained more extensive consideration, and engaged the attention of a different class of writers. Of these, Mr. John Dalton was the first chemist who attempted a full investigation of the theory of

vapour. He distinguished himself by "an accurate series of experiments on the expansive force of steam at temperatures under 212°. He ascertained various phenomena, and made experiments relative to the expansion of gases, the mixture of air and vapour, and the nature of evaporation and combustion. He did not succeed in his attempts to reduce any of these to general laws; but he gave such an impulse to the inquiry, as eventually to render it one of universal research among chemical philosophers; though owing to the prevailing idea that Watt had already exhausted the subject; that his experiments and results had made us sufficiently acquainted with the power and nature of steam; inquiry in this direction had been checked among men of science; and, at first, the importance of Dalton's experiments, and even their connection with the theory of the steam engine, were little noticed.

Although the use of steam of high pressure had been attentively considered and applied (to a working model at least) by Leupold—and had been the subject of applications for Patent Rights by Watt * and Matthew Murray—still, until this date (1801), it would appear that the idea of carrying out this simple and convenient mode of using steam as a motive power was reserved for the enterprize of two Cornish Engineers, Trevithick and Vivian.

The small amount of capital possessed by many of the owners of mines, and the constant necessity of having some adequate power to free them from water, together with the high prices demanded for Bolton and Watt's pumping engines, conspired to call the attention of these men to the necessity of providing some more economical and equally useful combination for obtaining the same end.

* It was generally understood, that although Mr. Watt patented the high pressure engine, it was not his intention that it should be employed except in situations where condensing water could not be had. He considered the risk too great and life too valuable to be endangered for the saving in the mere original cost of the engine, there being none in the consumption of fuel.

We may thus safely say, that the first useful application of high pressure steam is due to these two gentlemen. They were the first, also, who applied steam to produce locomotion upon rail-roads, to which purpose they adapted their high pressure engines; and, when used for this purpose, the boiler was composed of cast iron, of a cylindrical form, mounted horizontally upon a frame with four wheels, the cylinder of the engine being placed vertically within the boiler, near to one end. The piston-rod moved a cross-head between two guides; and, by a connecting rod descending from each end of the cross-head to two cranks, the motion was communicated to the wheels of the carriage: a fly-wheel in this case is not required, because the momentum of the carriage supplies its place.*

The first trial of this species of moving power for carriages took place on a rail-way at Merthyr Tydfil, in 1805. Its use was not at that period followed up, but it is now, with some improvements, used generally on all rail-roads.

Watt's patent for his mode of condensation, and Hornblower's patent also, having expired, Mr. Wolf combined the two cylinders of the latter with the condensing apparatus of the former, only using steam of high pressure in the small cylinder. The mere fact, however, of using higher steam, was too poor a title for a patent; consequently, he claims the discovery of a new law of the expansibility of steam, which he put forth as the result of actual experiment. He must, however, have made some curious mistake either in his calculations, or in the apparatus by which his experiments were effected. He asserted that steam, of any number of pounds' pressure above the pressure of the atmosphere, would expand to an equal number of times its volume, and still be equal in elastic force to the pressure of the atmosphere, the temperature being unaltered; hence, steam generated at forty pounds on the square inch, was

* It is but justice to observe, that Mr. Murdock made his working model of a locomotive engine in 1782; and that, as Mr. Trevithick was a pupil of Murdock's, then in Cornwall, it is natural to suppose that he received many of his ideas of locomotion from that gentleman.

expected to expand to forty times its own bulk, and yet be equal to the pressure of the atmosphere. But it is a well known law in the expansion of fluids, that the temperature being constant, the bulk is inversely as the pressure; and, calling the pressure of the atmosphere 14 pounds, we have $14:14\times40::1:4$, nearly. Therefore, steam generated at 54 pounds on the square inch, or 40 pounds above the pressure of the atmosphere, would expand only to four, and not to forty times its volume. (See article on this subject.)

Although Wolf's assertions were so directly opposed to the laws of the constitution of elastic fluids, they have found their way, as undoubted experimental truths, into works which ought to have high claims to respectability.

In this year (1801), Oliver Evans applied to the Legislature of Pennsylvania for a patent for the "Application of High Elastic Steam, the great advantage of which," he says, "I had discovered, demonstrated, explained, and made known. I have dispensed with the heavy beam, condenser, and air pump, and simplified the construction of the boiler, cylinder, piston, and working gears: my plan requires a small forcing pump to supply the boiler. Thus I have produced an engine ten times as powerful, more governable, and easier varied to suit any task assigned to it than that of Bolton and Watt: it can be constructed at half the price, and will expend only one-third the fuel to do as much work as theirs."

It would appear that his attention had been called to the use of high pressure steam, from the circumstance of hearing of its immense force as exhibited by a boy to a brother of his, by means of an old gun barrel; of which, having stopped up the touch-hole, and having poured about a gill of water into it, he with a strong plug stopped up the muzzle, and then placing the breech in a smith's fire, after some time, the plug was driven out with a great *crack*. This circumstance occurred about the year 1772, whilst he was apprentice to a wheel-wright; and as he had long been trying to find out some motive power for conveying goods along the roads other than animal or human

power, the idea instantly struck him that here was the very thing he had sought so diligently. Soon after this occurrence, he met with some description of the old atmospheric engine, and his imagination was forthwith at work, how to modify this arrangement, so as to use the power of steam without condensation.

In the year 1786, he petitioned the Pennsylvania Legislature to grant him the exclusive right to use steam wagons in that State; but without success.

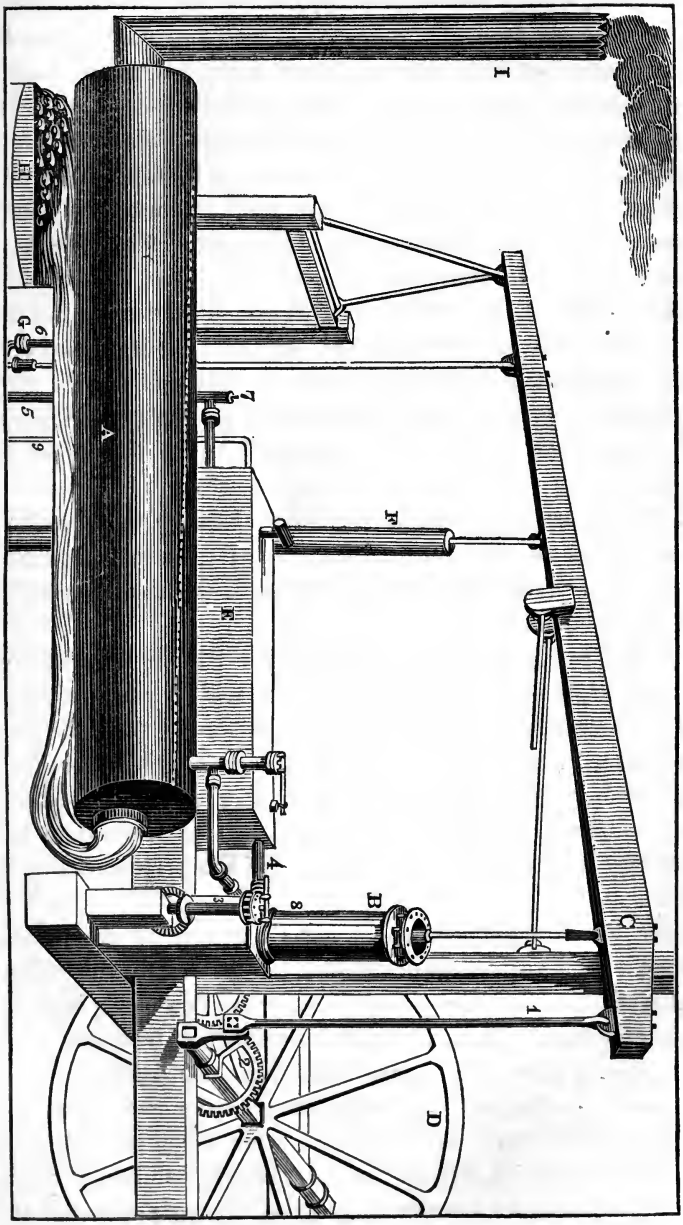
On the 21st of May, 1787, he obtained from the Legislature of Maryland an exclusive right to make and use steam wagons for the term of fourteen years, in that state; but it would appear that all his arguments were not sufficient to induce capitalists to join him in the speculation, so the projects were consequently dropped.

He now set to work and constructed an engine for a mill to grind plaister of Paris, which succeeded, and by which he could break and grind 300 bushels, or 12 tons, in twenty-four hours. The dimensions of this engine are as follows: the diameter of the cylinder six inches, and the length of stroke eighteen inches. The annexed wood cut represents the identical engine which he patented, and which turned the machinery in a shop at Philadelphia, where the writer worked ten years ago.

We will again use Mr. Evans' own words in the following description of his first using steam to propel a carriage and move a boat:

"In the year 1804, I constructed, at my works, situate a mile and a half from the water, by order of the Board of Health of the city of Philadelphia, a machine for cleaning docks. It consisted of a large flat or scow, with a steam engine of the power of five horses on board to work machinery, to raise the mud into flats. This was a fine opportunity to show the public that my engine could propel both land and water carriages, and I resolved to do it. When the work was finished, I put wheels under it (and though it was equal in weight to two hundred barrels of flour), and the wheels fixed with wooden

EVANS' ENGINE.



axletrees, for this temporary purpose, in a very rough manner, and with great friction, of course; yet, with this small engine, I transported my great burden to the Schuylkill with ease; and when it was launched in the water, I fixed a paddle-wheel in the stern, and drove it down the Schuylkill to the Delaware, and up the Delaware to the city (14 or 15 miles), leaving all the vessels going up behind me, at least half way, the wind being ahead, and in the presence of thousands of spectators—a sight which I supposed would have convinced them of the practicability of both steam carriages and steam boats. But in this I was sadly disappointed; for they made no allowance for the disproportion of the engine to its great load, nor for the temporary manner in which it was fixed, nor the great friction, ill form of the boat, &c., but supposed it was the utmost I could do."

Mr. Evans here remarks—and with natural and excusable chagrin—at the same time casting a very just censure upon the want of energy and speculative spirit of the wealthy inhabitants of Philadelphia:

"Had I been patronised, as Mr. Fulton was by the State of New-York, with the exclusive right for thirty years, and by a Mr. Livingston with thirty thousand dollars, to make the experiment, I might have showed steam boats in full operation long before Mr. Fulton began his boat, which was finished in 1807, twenty years after I petitioned the Legislature of Pennsylvania, and three years after the above mentioned experiment."

Mr. Evans entertained many ideas which, in his day, were thought almost evidences of insanity, but we see that his wildest schemes either have already been or are now being carried into execution. Thus, locomotive engines are travelling at a rate of sixty miles an hour, and Perkins has raised the pressure of steam to a degree far exceeding the pressure or elasticity of ignited gunpowder. His, however, were not all speculative theories even in his own day, as the following will fully show:

"The principles are now in practice, driving a saw-mill at

Mauchack's, on the Mississippi; two at Natchez, one of which is capable of sawing 5,000 feet of boards in twelve hours; a mill at Pittsburgh, able to grind twenty bushels of grain per hour; one at Marietta, of equal powers; one at Lexington, Ky., of the same powers; one, a paper-mill, of the same; one of one-fourth the power, at Pittsburgh; one at the same place of three and a half times the power, for the forge, and for rolling and splitting sheet iron; one of the power of twenty-four horses, at Middletown, Conn., driving the machinery of a cloth manufactory; two at Philadelphia, of five or six horses; and many making for different purposes: the principle applying to all purposes where power is wanted."

We will now close our notice of this enthusiastic and ingenious inventor with a few of his predictions in 1813:

1. "The time will come, when people will travel in stages moved by steam engines, from one city to another, almost as fast as birds fly—fifteen or twenty miles an hour.

2. "A carriage will set out from Washington in the morning; the passengers will breakfast at Baltimore, dine at Philadelphia, and sup at New-York the same day.

"To accomplish this, two sets of rail-ways will be laid, travelled by night as well as by day, and the passengers will sleep in these stages as comfortably as they now do in steam stage boats.

3. "A steam engine, consuming from a quarter to a half cord of wood, will drive a carriage 180 miles in twelve hours, with twenty or thirty passengers, and will not consume six gallons of water.

4. "These engines will drive boats ten or twelve miles per hour, and there will be many hundred steam boats on the Mississippi,* and other western waters, as prophesied thirty years ago.

* Mr. Evans lived to know, that in 1813, there were three steam boats on the Mississippi; and recent information gives the number as over 1,000 vessels; most of which have been built at Pittsburgh, Wheeling, and Cincinnati.

"Posterity will not be able to discover why the legislature or Congress did not grant the inventor such protection as might have enabled him to put in operation these great improvements sooner, he having asked neither money, nor a monopoly of any existing thing."

PART II.

PROPERTIES OF STEAM.

CHAPTER I.

PROPERTIES OF STEAM.

First Cause.—Heat.—Effects.—Solids.—Liquids.—Gases.—Thermometer.—Table of Properties of Bodies.—Table of Expansion of Water by Heat.—Barometer.—Steam Guage.—Tables of Elastic Force of Steam.—Rules for Calculating the same.—Salt, or Sea Water.—Analysis.—Salinometer.—Motion of Steam.—Table of Motion.—Expressions of Force of Steam.—Rules for Calculating.—Velocity of Steam.—Bent Pipes.—Table of Properties of Steam.—Loss by Cooling.

1. The first subject of inquiry is that of *heat*, the agent used in the production of steam.

2. The natural and perceptible effect of heat when applied to different substances tends, in some, to expand and dilate their bulk to the altering their form and appearance; in others, entirely to dissolve and separate their component parts or atoms. Its action on metals is evidence of the former, and its operation on liquids an example of the latter process.

3. Of the actual nature of heat we may be said to know nothing, further than what is evident to the senses, by its action on the body, or its visible effects on matter: it would be vain, therefore, to waste time in wild conjecture or idle speculation, when it is in our power to note its action upon substances presented to its operation, and by this means establish such rules as may be useful in the following inquiries.

4. On the application of heat, the expansion and contraction of solids are various as their respective nature or qualities; but

the same material will expand and contract in all cases alike; regard being had that the bulk and temperature are the same.

5. The case, however, with liquids is widely different, hardly any two expanding alike, or even expanding in any equal degree, for an equal increase of heat at different temperatures. The expansion is less rapid, the nearer it approaches the point at which it congeals, and more rapid as it nears its boiling point.

6. In elastic fluids the case is again different; whether gases or vapours are subject to its action, a change of temperature causing an equal and uniform expansion, which expansion is the same in all.

7. To the study and knowledge of the above well-established facts, does that beautiful and useful little instrument the thermometer, or heat measure, owe its existence; but as its construction and use are now so generally understood, we may be spared the repetition of its description.

8. To assist us further in our subject, we will here subjoin the result of many experiments made by those who have devoted much time and ability towards their compilation, and on whose accuracy we may rely.

TABLE I.—*Containing some of the Properties of various Bodies.*

Names of bodies.	Melting and boiling points	Contracts in cooling in parts of an inch for each foot in length.	Expands in heating from 32 to 212 deg. Fahrenheit, the length being 1.00000.	Power of conducting heat.
Cast iron melts . .	17.977°	.124	.00111	1.2
Wrought iron, welding hot .	12.780	.137	.00122	1.1
Copper melts . . .	4.587	.193	.00172	1.0
Brass melts . . .	3.807	.210	.00187	1.0
Steel, red hot . . .	1.077	.133	.00118	
Zinc melts	700	.329	.00294	
Mercury boils . .	660	.	.01851	
Lead melts	594	.319	.00286	2.5
Bismuth melts . .	476	.156	.00139	
Tin melts	442	.278	.00248	1.7
Water boils	212	.	.04002	

10. Thus having some certain data with regard to solids, we here insert a table of the expansion of water by heat.

TABLE II.—*Showing the Expansion of Water by Heat.*

Temperature.	Expansion.	Temperature.	Expansion.
12° F.	1.00236	122° F.	1.01116
22	1.00090	132	1.01367
32	1.00022	142	1.01638
42	1.	152	1.01934
52	1.00021	162	1.02245
62	1.00083	172	1.02575
72	1.00180	182	1.02916
82	1.00312	192	1.03265
92	1.00477	202	1.03634
102	1.00672	212	1.04012
112	1.00880		

12. Before taking into consideration the elastic force of steam and the rules for calculating the same, it will be well to explain the means used for practically measuring it, and the reason for using such means.

13. If a glass tube closed at one end, and rather more than 30 inches long be filled with mercury, and then inverted into a vessel containing mercury, so that only about 28 inches of the tube may be above the surface of the mercury in the vessel, the mercury in the tube will remain suspended; if the tube, however, be gradually raised in a vertical direction until more than 30 inches are above the level of the surface in the vessel, the mercury will descend in the tube until it shall be just 30 inches above the level in the vessel.

14. The mercury will not always, however, remain stationary at 30 inches, but will vary its height according as the atmosphere is lighter or heavier; or according to the relative position the surface of the mercury in the vessel bears to the level of the sea, where the mean pressure of the atmosphere will support a column of mercury of 30 inches in height. The pressure of this column on a base of one square inch, will equal the

weight of 30 cubic inches of mercury, which weigh just 15 lbs.; which is the pressure of the atmosphere upon a square inch of surface.

15. This fact being established, it remains to show how it is to be applied to measuring the elastic force of steam.

16. A tube is provided, which is bent up like an inverted syphon, or in the shape of the letter U, and the bent part filled up to a certain level with mercury; if one end of this be attached to the vessel in which the steam is generated, and the other end open to the atmosphere, when the steam exerts a pressure on the surface of the mercury (in the leg of the syphon to which it has access) greater than the atmospheric pressure, the surface in the other leg will rise in proportion, and the difference of level between the two will be the measure of the excess of steam over the atmospheric pressure.

17. The following table will show the elastic force of steam at various degrees of temperature—the result of minute and careful inquiry. The names of the experimentors and the results obtained being placed in juxta-position, for the purpose of comparison.

TABLE III.—*Comparative of the Results of a series of Experiments on the Elastic Force of Steam.*

Temperature.	Robison's.	Dalton's	Ure's.	Southern's	Taylor's.	Rule.
	Experim't.	Experim't.	Experim't.	Experim't.	Experim't.	
24°	. .	. .	0.170	. .	. .	0.118
32	0.0	0.2	0.200	0.16	. .	0.172
36	. .	*0.29	. .	. .	. .	0.201
40	0.1	. .	0.250	. .	. .	0.245
42	. .	. .	. .	0.23	. .	0.266
43¼	. .	0.297	. .	. .	. .	0.281
50	0.2	. .	0.36	. .	. .	0.37
52	. .	. .	. .	0.35	. .	0.401
54½	. .	0.435	. .	. .	. .	0.442
55	. .	. .	0.416	. .	. .	0.45
60	0.35	. .	0.516	. .	. .	0.55
62	. .	. .	. .	0.52	. .	0.587
64	. .	*0.75	. .	. .	. .	0.633
65¾	. .	0.63	. .	. .	. .	0.675
70	0.55	. .	0.726	. .	. .	0.78
72	. .	. .	. .	0.73	. .	0.842
77	. .	0.91	. .	. .	. .	1.00
80	0.82	. .	1.010	. .	. .	1.106
82	. .	. .	. .	1.02	. .	1.182
88¼	. .	1.29	. .	. .	. .	1.447
90	1.18	. .	1.36	. .	. .	1.53
92	. .	. .	. .	1.42	. .	1.629
96	. .	*1.95	. .	. .	. .	1.84
99½	. .	1.82	. .	. .	. .	2.05
100	1.6	. .	1.86	. .	. .	2.08
102	. .	. .	. .	1.96	. .	2.21
110	2.25	. .	2.456	. .	. .	2.79
110¾	. .	2.54	. .	. .	. .	2.85
112	. .	. .	. .	2.66	. .	2.95
120	3.0	. .	3.30	. .	. .	3.68
122	. .	3.5	. .	3.58	. .	3.89
130	3.95	. .	4.366	. .	. .	4.81
132	. .	*5.07	. .	4.71	. .	5.07
133¼	. .	4.76	. .	. .	. .	5.24
140	5.15	. .	5.77	. .	. .	6.21
142	. .	. .	. .	6.10	. .	6.55
144½	. .	6.45	. .	. .	. .	6.95
150	6.72	. .	7.53	. .	. .	7.94
152	. .	. .	. .	7.90	. .	8 33
155¾	. .	8.55	. .	. .	. .	9.10
160	8.65	. .	9.60	. .	. .	10.05
162	. .	. .	. .	10.05	. .	10.52
167	. .	11.25	. .	. .	. .	11.7

TABLE III.—*Continued.*

Temperature.	Robison's.	Dalton's	Ure's.	Southern's	Taylor's.	Rule.
	Experim't.	Experim't.	Experim't.	Experim't.	Experim't.	
170°	11.05	. .	12.05	. .	. .	12.6
172	. .	. .	. .	12.72	. .	13.17
173	. .	*13.18	. .	. .	. .	13.46
178¼	. .	14.6	. .	. .	. .	15.1
180	14.05	. .	15.16	. .	. .	15.67
182	. .	. .	. .	16.01	. .	16.35
189½	. .	18.8	. .	. .	. .	19.15
190	17.85	. .	19.0	. .	. .	19.35
200	22.62	. .	23.60	. .	. .	23.77
200¾	. .	24.00	. .	. .	. .	24.07
210	28.68	. .	28.88	. .	. .	28.86
212	. .	30.00	30.00	30.00	30.00	30.00
220	35.8	*34.20	35.54	. .	34.95	34.92
225	. .	. .	39.11	. .	. .	38.32
230	44.5	. .	43.10	. .	41.51	42.00
240	54.9	. .	51.70	. .	50.00	50.24
250	66.8	. .	61.90	. .	59.12	59.79
250.3	. .	. .	. .	60.00	. .	60.00
260	80.3	. .	72.30	. .	70.10	70.8
270	94.1	. .	86.30	. .	82.50	83.45
272	. .	*88.9	. .	. .	. .	86.2
280	105.9	. .	101.90	. .	97.75	97.92
290	. .	. .	120.15	. .	114.50	114.4
293.4	. .	. .	. .	120.00	. .	120.50
295	. .	. .	129.00	. .	. .	123.5
300	. .	. .	139.70	. .	133.75	133.2
310	. .	. .	161.30	. .	. .	154.5
312	. .	. .	167.00	. .	. .	159.0
340	. .	*231.0	165.5	. .	. .	236.0
343.6	. .	. .	. .	240.00	. .	247.80
320	. .	. .	. .	. .	179.40	178.5

19. Thus, having placed before the eye what has been done by accurate experiment, we proceed to the rules for calculation deduced therefrom.

20. *Rule* 1. To find the force of steam in inches of mercury, the temperature being given.

Add 100 to the temperature, and divide by 177; the sixth power of the quotient is the force in inches.

Example. To find the force of steam for the temperature of 312.

$312 + 100 \div 177 = 2.3277$;

and $2.3277^3 = 159$ inches, the number for the force of steam in inches of mercury.

21. *Rule* 2. The force of steam being given to determine its temperature.

Multiply the sixth root of the force in inches by 177, and subtract 100 from the product, and the remainder will be the temperature required.

Example. Let the force of steam be 8 atmospheres, or 240 inches of mercury to find its temperature. The sixth root of 240 may be easily found by a table of squares and cubes, by first finding its square root, and then the cube root of the square root.

Thus the square root of 240 is 15.492, and the cube root of 15.492 is 2.493 ; hence $(2.493 \times 177 - 100 = 341.20$.

22. From the remarks already made in a former part of this chapter (art. 6), it will be understood, that when salt water is used for the production of steam, the force of the steam will be different, as it boils at a different temperature to fresh water.

23. The rules, therefore, just given will, when applied to salt water, require some correction; that is, the constant number which corresponds to a force of 30 inches of mercury, at the boiling point, with different degrees of saturation with salt, must be supplied, instead of the constant number for common water.

24. The following table gives the various boiling points, and constant numbers for different degrees of saturation.

TABLE IV.—*Of Boiling Point of Salt Water, &c.*

Proportion of Salt in 100 parts by weight.		Boiling point.	Constant number.	Constant log.
Saturated solution,	36.37 = $\frac{12}{33}$	226°	185.0	2.26703
	33.34 = $\frac{11}{33}$	229.9	184.3	2.26556
	30.30 = $\frac{10}{33}$	223.7	183.6	2.26396
	27.28 = $\frac{9}{33}$	222.5	183.0	2.26234
	24.25 = $\frac{8}{33}$	221.4	182.3	2.26086
	21.22 = $\frac{7}{33}$	220.2	181.6	2.25923
	18.18 = $\frac{6}{33}$	219.0	181.0	2.25760
	15.15 = $\frac{5}{33}$	217.9	180.4	2.25610
	12.12 = $\frac{4}{33}$	216.7	179.7	2.25446
	9.09 = $\frac{3}{33}$	215.5	179.0	2.25281
	6.06 = $\frac{2}{33}$	214.4	178.3	2.25130
Sea Water,	3.03 = $\frac{1}{33}$	213.2	177.6	2.24950
Common Water,	0	212.	177.0	2.24797

25. According to an analysis made by Dr. John Murray, 10,000 parts of sea water, of the specific gravity 1.029, contain

Muriate of soda, ...	220.01 = $\frac{1}{46}$
Sulphate of soda, ...	33.16 = $\frac{1}{302}$
Muriate of magnesia, ... , . .	42.08 = $\frac{1}{238}$
Muriate of lime, ...	7.84 = $\frac{1}{1276}$
	303.09 = $\frac{1}{32}$

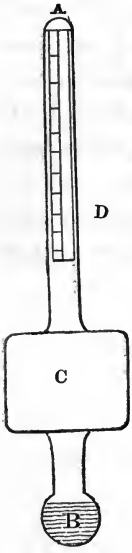
or one part of sea water contains .030309 parts of salts, which equals $\frac{1}{33}$ of its weight.

26. To enable the engineer, or person using the boiler, to ascertain with a considerable degree of accuracy the exact proportion of salt that is held in solution by the water he is then using, a little instrument is used, called the salinometer, of which the following is a description :—

A is a small glass tube, having an enlarged part C, to render it bouyant, and having a globe or bulb B below that, filled to a certain extent with very fine shot or quicksilver, which serves to keep it in a vertical position when immersed in water, and also causes the instrument to sink to a certain depth. D is an index

of paper fixed in the inside of the tube with certain marks and figures thereon, which we shall explain in describing its adjustment.

DIAGRAM 1.



27. Many persons are in the habit of adjusting their own instruments, to suit either their particular systems of calculation or according to their ideas of convenience. The process of adjustment is as follows:—The top of the tube A is open, and a vessel of rain water procured, of sufficient depth, to allow the immersion of the tube to extend to nearly its whole length. Fine dust shot or quicksilver is then poured into the tube, which falls into the bulb B, and causes the tube to sink down to the required depth; a mark is then carefully made on the tube at the level of the water. The tube is then withdrawn; and supposing the vessel to contain exactly one gallon of water, having decided upon what proportions he will use, the person puts in, say 1 oz. of salt, which being entirely dissolved, he again inserts the tube, owing to the increased specific gravity of the water, the tube does not sink so deep as before; he marks as before the level of water, and repeats the operation until he has gone high enough; he then marks on a small slip of paper the different levels he has already noted, and opposite to them the number of parts of salt held in solution, either calculating by weight or bulk. This paper is attached by gum or other means inside the tube, and in the proper position; the end is then hermetically sealed by means of the blow-pipe, and the instrument is complete.

According to the number of quantities of salt admitted and their correspondent marks, will be the value of the instrument.

28. Thus, therefore, with this instrument and the foregoing table, any person can tell accurately the amount of temperature required to produce a given effect or pressure in the steam;

that is, within the bounds of the table, which will rarely be exceeded.

29. We now proceed to consider the motion of steam, and the readiest way of investigating the subject will be to ascertain the height of a column of the same fluid which shall exert a pressure equal to the pressure to which the steam is subjected. Then the fluid will rush into a vacuum with the same velocity that a ponderous body would acquire in falling through the height of the above mentioned column—due reduction being made for the contraction of the aperture or passage.

30. From experiments already made, it appears that an action takes place tending to retard the motion of steam in the passage of apertures the same as in water.

TABLE V.—*Of Motion of Elastic Fluids.*

The velocity of motion that would result from the direct unretarded action of the column of the fluid which produces it being unity	1.000 or 8.
The velocity through an aperture in a thin plate by the same pressure, is	.625 or 5.
Through a tube from two to three diameters, projecting outward	.813 or 6.5
Through a tube of the same length, projecting inward	.681 or 5.45
Through a conical tube or mouth-piece, of the form of the contracted vein	.983 or 7.9

32. As the force of steam is variously expressed by pounds on a square inch, by inches of mercury and by atmospheres, we subjoin a table of the height of a column of water, which is equal to the above measure.

Height of a column of water at 60° =

1 lb. per square inch, . . .	2. 31 feet.
1 lb. per circular inch, . .	2. 94 feet.
1 inch of mercury, ...	1.333 feet.
the atmosphere, ...	34.00 feet.

Then, by multiplying any of the terms by the relative bulk and pressure, the height of the column of steam will be found.

33. The rule for finding the volume or space of the steam

produced from a cubic foot of water at any given force or temperature, is as follows :—

Rule. To 459 add the temperature, and multiply the sum by 76.5 ; divide the product so obtained by the force of steam in inches of mercury, and the result will be the volume or space occupied by the steam.

34. The height of a column of steam being found equivalent to the pressure of steam on the boiler, and also the height of a column equal to the pressure on the piston, the velocity will be equal to 6.5 the square root of the difference between the heights of the two columns. This will give the velocity in feet per second through a straight pipe ; for other forms or passages take the number from table (art. 31).

35. The rule just stated being for pipes without obstructions, and having no data for such pipes as occur in engines, allowance must be made for the reduction of speed on the same principles which obtain in similar circumstances. Thus $\frac{1}{10}$ of the velocity may be deducted for each right-angled bend, $\frac{1}{50}$ for an obtuse angle or regular curve ; and if a pipe be terminated in a valve-box, $\frac{2}{10}$ should be allowed for passing the valve.

36. For the purpose, however, of saving time in calculations, a table of the properties of steam of various degrees of elastic force is subjoined.

TABLE VI.—*Of the Properties of the Steam of Water of different degrees of Elastic Force.*

Total force of Steam.			Excess of force above the Atmosphere.		Temperature of Fahrenheit.	Volume in cub. ft., water being 1	Weight of a cub. foot in grains.	Specific gravity, air being 1.	Velocity into a vacuum in ft. per second.	Heat of conversion from water of 52° to steam.
In atmospheres.	Inches of Mercury.	In lbs. per circ. inch.	In lbs. per circ. inch.	In lbs. per sq. inch.						
.0183	.55	.21	−11.33	−14.4	60°	72190	6.1	.0115	1377	1008°
.0333	1.	.385	11.155	14.2	77°	41010	10.7	.0202	1400	1025
.0667	2.	.77	10.77	13.7	98.7	21400	20.5	.0388	1427	1047
.1	3.	1.15	10 39	13.2	112.5	14570	30 0	.0568	1445	1061
.133	4.	1.54	10.0	12.7	123.0	11130	39.0	.0744	1458	1071
.25	7.5	2.88	8.66	10.99	147 6	6187	71.0	.134	1499	1096
.5	15.	5.77	5.77	7.33	178.0	3249	135.0	.255	1526	1136
,75	22.5	8.65	−2.89	−3.66	197 4	2232	196.0	.371	1549	1146
1.00	30.	11.54	0.	0.	212.0	1711	254.7	.484	1566	1160
*1.17	35.	13.46	*1.92	*2.44	220.	1497	292.	.553	1575	1168
1.5	45.	17.31	5.77	7.33	233.8	1178	363.	.687	1591	1182
1.75	52.5	20.19	8.65	10.99	242 5	1022	427.	.81	1601	1191
2.0	60.	23.08	11.54	14 65	250.2	905	483	.915	1610	1199
2.5	75.	28 85	17.31	21.98	263.5	737	593.	1.123	1625	1212
3.0	90.	34.62	23.08	29.3	274.7	623	700.	1.33	1638	1223
3.5	105.	40.39	28.85	36.63	284.5	542	810.	1.53	1649	1233
4.	120.	46.16	34 62	43.95	293.1	479	910.	1.728	1658	1241
5.	150.	57.7	46.15	58.60	308.	391	1110.	2.12	1674	1256
6.	180.	69 24	57.7	73 25	320.6	331	1317.	2.5	1688	1269
7.	210.	80.78	69.24	87.90	331.5	288	1520.	2.88	1700	1280
8.	240.	92.32	80.78	102.55	341.2	255	1660.	3 25	1710	1289
9.	270.	103.86	92 32	117.20	350.	229	1910.	3.61	1720	1298
10.	300.	115.4	103 86	131.85	358.	209	2100.	3.97	1729	1306
20.	600.	230.8	219.26	278.35	414.	111	3940.	7.44	1786	1362
30.	900.	346 2	334.66	424.85	450.	77	5670.	10.75	1823	1398
40.	1200.	461.6	*450.06	*571.35	477.	60	7350.	13 88	1850	1425

* The usual force of low pressure steam.

37. There is another cause for the reduction of the velocity of the steam in its passage to the cylinder, namely, loss of elastic force by cooling, which is directly as the surface, and inversely as the quantity is exposed.

CHAPTER II.

COMBUSTION.

Production of Steam.—Combination of Combustible Matter.—Oxygen.—Means of increasing Combustion.—Blowing Cylinders.—Bellows.—Fan.—Table of Dimensions.—Properties of Fuel—Comparative Values.—Coals.—Parke's Table.—Rules for Calculating Quantities.

38. STEAM being produced by the action of heat upon water —and heat being evolved during the process of combustion—which is effected by the intimate combination of certain bodies with a class of substances called supporters of combustion. In the present case, however, we have to do with but one of them; namely, Oxygen.

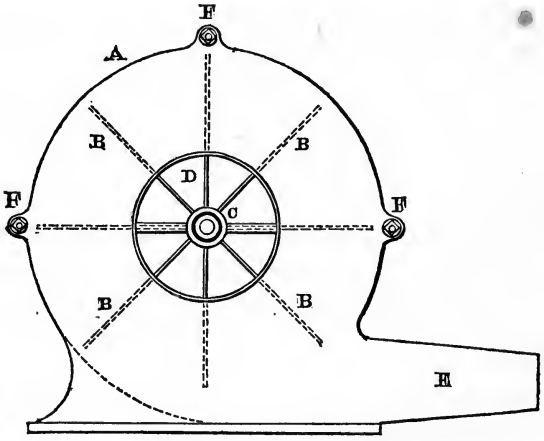
39. Oxygen combines in a greater or less degree with nearly all simple substances; and the consequence of this combination is, the exhibition of a greater or less degree of heat, according to the energy of the action by which the combination is effected.

40. Oxygen forms also one of the principal ingredients of which the atmosphere is composed, namely, about one-fifth of the whole—and it is from this source that the oxygen is derived which supports combustion. Therefore, as the oxygen during combustion forms a combination with the fuel or combustible body, it is necessary that its admission be as free as possible; otherwise, if retarded or kept back, combustion declines or altogether ceases. In many cases, it is absolutely necessary that the atmospheric air should be forced into contact with the fuel, the supply of air alone not being sufficient to produce the required combustion or heat. Here, then, we have

recourse to mechanical means, as in the blowing cylinders, for the furnaces in which metals are smelted, or in the smaller furnaces called cupolas, used in our foundries for the purpose of casting different articles. The commonest and best known apparatus for assisting combustion is the bellows.

41. For this purpose, however, the most convenient form is that called the *fan*—more particularly when applied to the furnaces of steam-boat boilers, on account of its facility of operation, and the comparatively very small space it occupies. As the fan or blower is now getting into very general use, the annexed diagram, explanatory of its formation and operation, may not be misplaced.

DIAG. II.



42. A, a case or drum of cast iron, having a hole D at either end. B, the fan; C, the spindle, upon one end of which is a small pulley, which is connected to a larger one, by means of a strap or belt running round the two, and from which it receives its motion, varying in velocity according to the force of current required; E, the pipe, or passage for conducting the air to the furnace; F F F, small bolts to retain the sides.

43. The following table will show the dimensions and velocities of blowers now in use:

TABLE VII.—*Showing the dimensions of Blowers now used.*

Diam.	Depth of Fan.	Width of Fan.	Holes.
24 in.	6	12 inches.	12 in.
20	4	10	10
19	4	9	9

44. In the use of anthracite or stone coal, the blower is of very great assistance ; rendering the combustion very complete and rapid, and, consequently, raising a greater quantity of steam from a given quantity of fuel. Many kinds of blowers have been invented and tried, their chief excellence being, apparently, in their novelty and complication. The conical reacting blower attracted much attention at the time of its invention, but it has long since ceased to be considered advantageous.

45. Of the various kinds of fuel in use, the most common in this country are four, namely :

Pine Wood,
Hard Wood,
Bituminous Coal,
Anthracite Coal.

From experiments made on the relative value of the above kinds of wood, by Mr. Bull, it would appear that shell-bark hickory was the most and white pine the least valuable. We subjoin, however, a table of the results, showing the comparative value of a cord of each kind, together with its weight.

TABLE VIII.—*Comparative value of a Cord of different kinds of Wood.*

Kind of Wood.	Weight of Cord.	Comparative value of Cord.
Shellbark Hickory	4469 lbs.	100
Pignut Hickory	4241 "	95
Red-heart Hickory	3705 "	81
White Oak	3821 "	81
Red Oak	3254 "	69
Hard Maple	2878 "	60
Jersey Pine	2137 "	54
Pitch Pine	1904 "	43
White Pine	1868 "	42

47. The elative value of the heating powers of bituminous and anthracite coal has been variously stated. The following table, compiled from the latest experiments, will be found useful for general purposes:

TABLE IX.—*Comparative value of Coal and Wood.*

Species of Fuel.	P'ts of Litharge reduced.	lbs. water heated ° by 1 lb. fuel.
Oak, seasoned	12.5	4790
do. artificially dried	14.	5350
Nut wood	13.7	5240
White Pine	13.7	5240
Yellow Pine	14.5	5550
Charcoal	25 to 32	
Turf	8 to 15	
Charred Turf	17 to 26	
Lignite	17 to 27	
Coal, Welsh	31.2	11840
" Newcastle	30.9	11815
" Wigan	28.3	9820
" Belgium	29.	11090
" Durham	31.6	12080
Coke, good	28.5	9910
" inferior	22.2	7380
Anthracite, French	29.	11090
" Pennsylvania	25.	9560

49. For the purpose of further facilitating the calculation of the cost and consumption of fuel, the following table is added, giving the quantity of coal requisite for raising water from 32° to 212,° and from 212° for evaporating the same.

50. The comparative value of bituminous and anthracite coal, or bituminous coal and wood, is already given in the foregoing tables. This table, therefore, will be sufficient to render the calculation of comparative expense or economy a matter of very easy access.

The table was compiled by Mr. J. Parkes, of Warwick, England, and published in the second volume of the Trans. of Soc. of C. E., London, March 5th, 1838.

TABLE X.—*Showing the quantities of Coal requisite to boil and evaporate.*

Temp. of the water.	Coal burnt in heating to 212°. lbs.	Coal burnt in evapo-rat'g from 212°. lbs.	Temp. of the water.	Coal burnt in heating to 212°. lbs.	Coal burnt in evapo-rat'g from 212°. lbs.	Temp. of the water.	Coal burnt in heating to 212°. lbs.	Coal burnt in evapo-rat'g from 212°. lbs.
32°	17.84	94.16	94°	12.37	99.63	154°	6.44	105.56
34	17.67	94.33	96	12.18	09.82	156	6.23	105.77
36	17.50	94.50	98	12.	100.	158	6.02	105.98
38	17.33	94.67	100	11.81	100.19	160	5.81	106.19
40	17.16	94.84	102	11.62	100.38	162	5.6	106.4
42	17.	95.	104	11.43	100.57	164	5.38	106.62
44	16.83	95.17	106	11.24	100.76	166	5.17	106.83
46	16.65	95.35	108	11.05	100.95	168	4.95	107.05
48	16.48	95.52	110	10.85	101.15	170	4.74	107.26
50	16.31	95.69	112	10.66	101.34	172	4.52	107.48
52	16.14	95.86	114	10.47	101.53	174	4.30	107.70
54	15.97	96.03	116	10.27	101.73	176	4.08	107.92
56	15.79	96.21	118	10.08	101.92	178	3.86	108.14
58	15 62	96.38	120	9.87	102.13	180	3.64	108.36
60	15.44	96.56	122	9.69	102.31	182	3.42	108.58
62	15.27	96.73	124	9.49	102.51	184	3.20	108.80
64	15.09	96.91	126	9.29	102.71	186	2.98	109.02
66	14.91	97.09	128	9.09	102.91	188	2.75	109.25
68	14.74	97.26	130	8.89	103.11	190	2.53	109.47
70	14.56	97.44	132	8.70	103.30	192	2.30	109.70
72	14.38	97.62	134	8.49	103.51	194	2.08	109.92
74	14.20	97.80	136	8.29	103.71	196	1.85	110.15
76	14.02	97.98	138	8.09	103.91	198	1.62	110.38
78	13.84	98.16	140	7.89	104.11	200	1.39	110.61
80	13.66	98.34	142	7.68	104.32	202	1.16	110.84
82	13.48	98.52	144	7.48	104.52	204	0.93	111.07
84	13.29	98.71	146	7.27	104.73	206	0.70	111.30
86	13.11	98.89	148	7.06	104.94	208	0.46	111.54
88	12.93	99.07	150	6.86	105.14	210	0.23	111.77
90	12.74	99.26	152	6.65	105.35	212		112.
92	12.56	99.44						

CHAPTER III.

BOILERS.

Neglect of the Subject.—Old Method of Calculation.—Watt's Twenty Horse Boiler.—Form and Dimensions.—Capacity.—Furnace.—Depth of Water.—Flues and Heating Surface.—Tubular Boilers.—Form.—Dimensions.—Rule.—Action of Fire.—American Boilers.—Improvement.—Locomotive.

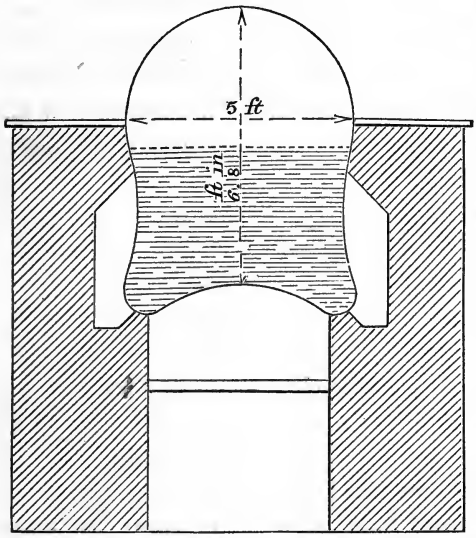
52. Notwithstanding the many and valuable improvements which have been added to the machinery and working parts of the Steam Engine since the days of the illustrious Watt, it is matter of surprise that, until within the last few years, so little attention has apparently been paid to the construction and use of the boiler.

53. The extraordinary economy of the steam engine, as compared with animal power, is a subject of daily observation; and yet, until lately, no just comparison could be made, as the theory and practice of using fuel previously was a subject nearly, if not altogether, overlooked.

54. *Form and Dimensions.*—In the first place, then, let us inquire into the usual form and dimensions of the boiler as used by Mr. Watt, and the rules generally employed for calculating the size required for an engine of any number of horses' power. The system which has hitherto obtained (rule it cannot be called) amongst engine and boiler makers, is to endeavour to make them larger than necessary; consequently, a ten horse engine will have a twelve or fifteen horse boiler, and a twenty horse

engine a thirty horse boiler. The usual allowance of water, surface and space for each horse power, was about five square feet for the former, and twenty-five cubic feet for the latter.—The annexed diagram, we will suppose, represents the section

Diag. III.



of a twenty horse boiler, 5 feet wide, 6 feet 8 inches deep, and 20 feet long; then, to ascertain its contents, we must find the sectional area, and multiply by the length. The upper part is the half of a cylinder 5 feet diameter and 20 feet long; and $\frac{5^2 \times .7854}{2}$ =196.35 cub. feet. The lower part, if made with its sides and bottom flat, would contain $4.1666 \times 5 \times 20 = 416.66$ cubic feet; but the sides are concave, and the bottom also, which reduces the above amount by about one sixth, $\frac{416.66}{6} = 69.44$ cubic feet, and 416.66—69.44=347.22 cubic feet, to which add contents of top 196.35=543.57, and $543.57 \div 27 = 20.13$ cubic yards, which is the capacity of the boiler. One half of this space is allowed for water, and the remainder for steam room. But some allowance must be made for the stays, which are necessary on account of the shape; then about half a cubic yard is left for water room, and half a cubic yard for steam room, for each horse power. The peculiar form of the sides and bottom is to cause the heat, &c. in its passage round the boiler and along its bottom, to impinge or press against the sides, instead of merely passing by.

56. *Furnace.*—The usual dimensions of the furnace for such a boiler are: for the fire bars, five feet long and four feet wide; giving an area of twenty feet, or one square foot per horse power.

57. *Depth of Water.*—To find the requisite depth of water in the boiler, the following rule is used: Take half the difference of capacity between the lower and upper part, and divide it by the area of water surface, then deduct the quotient from the depth of the lower part, and the remainder is the depth of water; measuring from the seating plate of the boiler perpendicularly. Thus:

Capacity of lower part, = 347.22
Do upper part, = 196.35

2)150.87

Area of water surface = 75.43

$5 \times 20 = 100$ and
75.43 divided by 100 = .7543 quotient;

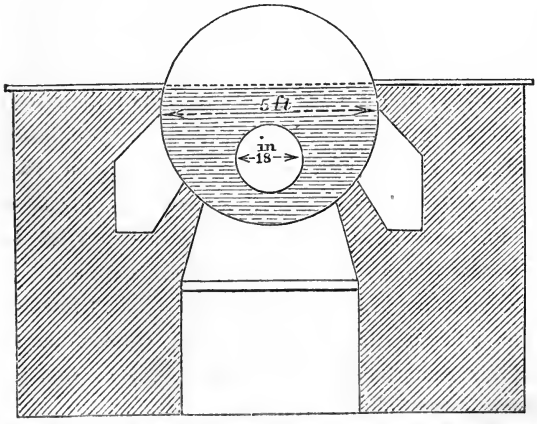
which, subtracted from 4.1666, the depth of lower part, gives 3.4123 feet, or 40.9476 inches. Hence the requisite depth of water was three feet five inches, nearly.

58. *Flues and Heating Surface.*—The brick work of the side flues is gathered in two or three inches below the water level, and consequently the side surface is reduced to about 3.5 feet, and the total area for both sides is $3.5 \times 2 \times 20 = 140$ square feet. The area of the ends below the tops of the flues is about 28 square feet, minus the surface covered by the brick arch over the furnace door, which about = 3 square feet; and by the brick work of the back end which divides the uptake from the side flue, which equals about two square feet; hence these numbers subtracted from 28 leave 23, and $23 + 140 = 163$ square feet of surface; but about one half of this only is effective as heating surface, therefore we have only 81.5 square feet, or 9.05 square yards. But the whole area of bottom is

effective; and, measuring the curved surface, is = about 94 square feet, or 10.4 square yards; consequently, the whole effective surface = 10.4+9.05=19.45, or nearly 20 square yards.

59. From what has been shown of the twenty horse boiler, and from experiments made by scientific persons, we find that it requires one cubic foot of water to be evaporated per horse power per hour; and one cubic foot of water requires nine square feet or one square yard of heating surface, and one square foot of fire grate. The *wagon boiler*, as this is called, is much used in the manufacturing districts of England, and is sometimes made of enormous size. It answers only for low pressure steam.

60. *Tubular Boilers.*—Where high pressure steam is required, tubular boilers (so called) are generally made use of, chiefly on account of the shape; the cylindrical being a much stronger form for resisting pressure, either externally or internally, than the wagon shape. The diagram below shows a section of one with an internal flue and split draught; that is, the smoke passes under the boiler, and through the tube, and then divides and returns on each side to the chimney or stack.



61. The dimensions are —in diameter, six feet; length, nine and a flue of 18 inches diameter, running from end to end; and the fire grate or furnace is three feet six inches square, or twelve and a quarter square feet area. This boiler, then, according to the rule above stated,

would be a nine horse power boiler; but many who are in the habit of making flued boilers, or, as they are commonly (though erroneously) called, tubular boilers, usually consider in their calculations that the diameter of the inside flue or tube is equivalent to so much added to the width of the boiler, the result of which is nearly correct, at least in cases where the boiler is not very long in proportion.

According, therefore, to this rule, the power of the boiler is found as follows:

Diameter of boiler =	5 feet.
Do. of inside flue =	1.5
	6.5
Multiply by length,	9
Divide by	5)58.5
Horses' power,	11.7, or $11\frac{3}{4}$ nearly.

By observation, the evaporation of this boiler only varied from ten to eleven cubic feet of water per hour.

62. The next class of boilers are those used for locomotive engines, of the peculiar construction of which, more will be said under the head of Locomotion. These boilers, or rather boilers constructed on the same principles, are now used with great success on board many of the steam boats: their extraordinary power of generating steam being so peculiarly adapted to the present system of using the steam engine (viz: using high pressure steam expansively); as they not only take up such little room, but admit of working up to a considerable pressure, when necessity may require, in so short a time.

63. These boilers were first applied by Mr. R. L. Stevens, in 1837, who has since made several different constructions, all of which answer remarkably well. The plans of several of these are shown in the volume of plates.

64. It would seem, however, that perfection is far from being attained in the art of constructing boilers; for nearly every

new boiler has some supposed improvement over the last, at least those made by the more intelligent engineers. Some manufacturers still use flues, varying in diameter from 8 to 18 inches, of which they have eight, ten, or more in each boiler. Of such construction are the boilers of the steamboat 'North America;' and, from the quantity of steam supplied compared with the small quantity of coal consumed, we should pronounce these amongst the best now in use—28.28 cubic feet of steam, of the pressure of fifty pounds per square inch being generated by the combustion of one pound of coal per minute.

65. There is yet another modification of boiler, the credit of which combination is the property of Mr. R. Schuyler. In this boiler (see plate 35), the heat passes off right and left through small tubes; it then enters a long flue, through the top of which it passes into other horizontal flues, whence it makes its escape to the funnel. This boiler produces 888.864 cubic feet of steam, at a pressure of twelve pounds per square inch, with the combustion of 7.879 lbs. of coal, per minute, or 112.8 cubic feet of steam from 1 lb. of coal at the same pressure.

66. The same enterprising gentleman has constructed several boilers since the above was first put in operation, all of which have fully answered his expectations.

67. Although, in the case of the 'Essex,' he had a very confined room for his operations—that is to say, the height from floor to deck being so limited, as it must necessarily be in boats of such small dimensions as ferry boats usually are—nevertheless, this boiler may with safety be declared to possess the greatest known generative power of any or all the marine boilers that have ever been constructed in this country.

68. Of the boilers used on the Western waters, little can be said, as they are merely cylindrical, and similar to that already described.

69. It is well known, though notice of the fact should not be omitted, that the surface in actual contact, and in close proximity to the fire, is many times more valuable than the surface which is further off; hence, in calculating the generating sur-

face, care must be taken to make proper allowance for the same. Some authors and practical men have defined this proportion at the rate of 3 to 1, 2 to 1, and 5 to 1; the latter probably being nearest to the fact.

PART III.

STEAM NAVIGATION.

CHAPTER I.

STEAMBOATS, &c. &c.

70. In the former part of this work we have considered the steam engine as made and applied, or ready to be applied to the purposes of pumping or raising water, or as the moving power for working mills or manufactories. We now, however, from its very great importance, turn to the application of this mighty power for the purposes of impelling or driving vessels either for ocean or inland navigation.

71. We have already seen to what state of perfection the steam engine had been brought in Europe up to the year 1801. (See plate I.) It was a double acting engine, capable of producing a continuous rotatory motion, by means of the crank and fly-wheel. In the year 1807, Fulton's first steamboat was in actual operation on the Hudson—preceding the Stevens' boat by a few days, and thus securing to himself the grant of the exclusive privilege of the State of New-York. The Stevens', however, although deprived of the waters of New-York, sent their vessel round by sea to the Delaware, where they immediately set it in operation.

72. Fulton, it appears, considered that the wave formed by the passage of the boat through the water presented an insurmountable obstacle to the production of any greater speed than eight or nine miles per hour; and this appears to be the speed that Fulton assigned for nearly all his boats.

73. During this period, R. L. Stevens was carefully examining into the form and arrangement of vessels best adapted for navigation at a greater velocity; and when the monopoly enjoyed by Fulton expired, he had a vessel ready which performed the voyage from New-York to Albany at the rate of 13½ miles per hour.

74. Stevens considered the slow speed of Fulton's earlier boats as chiefly attributable to the full bows or bluff entrance of the vessel; and was thus induced to bestow so much more attention on the architecture of these boats than he otherwise might have done. It is, therefore, most decidedly, to R. L. Stevens that we owe the present beautiful models of our North River boats, which for elegance and speed are justly considered the finest in the world.

75. The engine which Fulton first obtained from the establishment of Bolton and Watt, of Soho, was so made as to allow the crank shaft to be raised or lowered, for the purpose of applying greater or smaller paddle wheels—the exact dimensions of which could only be decided upon by practice. He subsequently altered the arrangement of the engine, and made it work like the engines of the 'Neptune' or 'Daniel Webster,' and it received the name of the cross-head engine. The cross-head works in guides on each side; therefore the motion of the piston-rod is kept perfectly vertical. The present form, however, of the cross-head engine with its many improvements, is unquestionably the production of Dr. Hart, many years foreman to Mr. James P. Allaire, of New-York.

76. Stevens used the Bolton and Watt engine with some alterations. Thus, he took away the parallel motion and substituted the guide-rods, as well as most materially improved the power of the boiler.

77. It was not until the year 1812 that steamboats were introduced into general use in Great Britain—five years after Fulton's successful voyage on the Hudson.

78. In 1815, Fulton commenced running steamboats from New-York to Providence, Rhode-Island, part of which passage is performed on the open sea.

79. In 1817, the steam vessel 'Savannah' made a voyage from New-York to Russia; and,

80. In 1818, a steam ship plied as a regular packet from New-Orleans to New-York, touching at Havana and Charleston.

81. In the year 1815, the first passage was made from Glasgow to London, in a steamboat, under the direction of Mr. George Dodd.

82. In 1820, the mail packets were established by the British Government to run from Holyhead to Dublin.

83. In 1825, a passage was made from London to Calcutta by the steam ship 'Enterprise.'

84. From the last date up to the present time, we have noticed a gradual improvement, as well in the machine itself as in the boilers and shape of the vessels.

85. In France, the progress of the steam engine, whether applied to manufacturing purposes or otherwise used, did not arrive at any degree of perfection until long after its successful use both here and in England; a circumstance which is attributable to the agricultural pursuit of its inhabitants, more than to any want of energy amongst the learned philosophers of that country.

86. We now come to an entirely new era in steam navigation, namely, the introduction of the system of using steam *expansively;* a system which we have already shown, was patented by Watt in 1778, and subsequently used with the most beneficial effects in connection with high pressure steam, by the engineers of Cornwall, who have fully tried and tested the merits of the system for many years, especially as to its economical qualities; the result is, that nearly every engine in use at the various mines in that country (and there are some hundreds of engines employed), are condensing engines, working with high steam, and using it expansively. The actual amount of saving has been variously estimated at from 75 to 50 per per cent.

87. Taking advantage of the above mentioned facts, Mr. Adam Hall (long the foreman at the West Point foundry), conceived the idea of using high steam, and cutting off the supply at $\frac{3}{4}$, $\frac{1}{2}$, or even $\frac{1}{4}$ of the stroke; thereby anticipating a saving, not only in the actual consumption of fuel, but also in time, by obtaining a greater velocity.

88. The first impulse being given, or rather the attention of the wealthy speculators in steam navigation being called to this circumstance, trials were immediately made, and their results proving every way satisfactory, the system at once obtained, and now it is the common practice of our engines to adopt the cut-off valve to all kinds of engines.

89. The many beneficial results springing from this cause induced others to enter upon the examination of the subject; and it was found by experiment and established by practice, thatmore work was done at a less expense by cutting off at $\frac{1}{4}$th, than by cutting off at $\frac{1}{2}$ the stroke; the pressure of the steam in the boiler being of course increased in proportion. Thus, the steamboats lately constructed, cut off at $\frac{1}{4}$, $\frac{1}{8}$, and some even at $\frac{1}{10}$th of the stroke, and the results are highly satisfactory. In another point of view, this has great advantages over the method of using dense steam (i. e. of allowing the cylinder to be filled at each stroke), in the fact of its only requiring $\frac{1}{4}$, $\frac{1}{8}$, or $\frac{1}{10}$th part the quantity of steam, thus requiring less boiler room and fuel—no inconsiderable desideratum in a steamboat. Many persons there are, however, who still persist in arguing (in the face of facts), that it is no more economical to use high than low pressure steam with the cut-off. We would advise those persons to ascertain how many pounds of coal are consumed per horse power per hour on board the new 'North America,' and compare that amount with the quantity used in the boats of an earlier date, and we are much mistaken if they will not find a saving of at least 50 per cent. in fuel, to say nothing of the speed, which has been just doubled.

90. The theory of high pressure expansive steam, we may safely venture to say, is not yet understood; and many persons who have attempted to analyze its operation and action, have most signally failed, either from the want of sufficient data, or from some misconception of its nature. So little, indeed, is the principle understood in England generally, even at the present day, that the work performed by the Cornish engines, for the fuel consumed, is hardly credited, nay, has been flatly denied

by some of the London engineers; the amount of work done so far exceeding what is usual for the best engines working with low pressure steam, although using it expansively; which plan, however, is infinitely more economical than not cutting off at all.

91. By means of the *Indicator, or Dynamometer, we can ascertain with considerable exactness what the engine is doing; and then, by knowing the quantity of coals consumed, we can arrive at the actual expense of the work done. It is by these means that the Cornish pumping engines are tested; and as the instrument is perfectly accurate in its results, there can be no doubt that the data of the calculations are correct.

92. To enable the reader to see clearly, for himself, the effect of the cut-off with high steam, we give the following well attested experiment on a celebrated Cornish engine, taken from a paper by Mr. Wicksteed, and read before the Society of Civil Engineers, of London, in the year 1837.

"I am induced to address you again (see vol. i. of Trans. of S. C. E.), on the subject of the engines used in the mines in Cornwall, from the very kind manner in which you received my last paper.

"I have been lately into Cornwall, having been instructed by the Directors of the East London Water Works Company to proceed there, for the purpose of examining an engine that was to be disposed of by the East Cornwall Silver Mining Company, with a view of purchasing it for the Company's works, at Old Ford. The result was, that the engine, the cylinder of which was 80 inches in diameter, was purchased, and is now being removed to London, and I expect by this time next year, will be at work here.

"While in Cornwall, I was very desirous of making such a trial of one of the engines, as might be satisfactory to the London Engineers, and trust that I have succeeded in my object.

* For description, see Part V.

"I received permission to make a trial of the engine upon the Holmbush mines, near Callington, and beg to give you the following detailed account thereof:

The diameter of the cylinder was fifty inches; the size of the pumps, or 'boxes,' as they are termed in Cornwall, and the height of the lifts are as follows, viz:

Tye lift,	42	fath.	2	ft.	6	in.	Diam of pump, 11 in.
Rose lift,	37	"	5	"	6		do 11 "
Bottom lift,	8	"	5	"	6		do 10 "

"The chief points to which my attention was directed, were the quantity of coal consumed, and the actual quantity of water lifted.

"I saw 94 lbs. (a Cornish bushel) of coals weighed, and had the stoke-hole cleared, and the coal-bins and stoke-hole doors sealed; and in addition to these precautions, besides my own observation, I had one of my young men stationed in the boiler house during the time of trial, so that I am quite satisfied that no more than 94 lbs. of coals were used.

"Before the trial, I ascertained exactly the length of the pump stroke, which was eight feet one inch, and caused the engine to work slowly, that I might have sufficient time to measure the quantity of water delivered per stroke. The water was delivered in a wooden cistern, with a valve to let the water out, when I had measured it. Finding that six separate measurements produced as nearly as possible the same result, the greatest variation being two per cent., I weighed the quantity of water delivered by each stroke, and found it to be equal to $285\frac{6}{10}$ lbs. I had a rod made the exact length of the stroke, namely, eight feet one inch, and during the trial measured the stroke frequently; it varied from eight feet one inch, to eight feet two inches. I have in my calculation taken the shortest length. The diameters of the pumps and exact height of the lifts were taken very carefully.

Trial.—The fire under the boiler was worked down as low as could be, without stopping the engine. The pressure of the steam was forty pounds to the square inch *in the boiler*. I

took the counter and the time, and then started the engine. At the end of two and a half hours the fire was lowering, and the speed of the engine reducing, and it was necessary to have more fuel. The 94 lbs. having been consumed, the engine was then stopped, and the counter again taken. It had made 672 strokes, or very nearly five strokes per minute. The weight of water raised was (285.6 × 672 strokes)=191,823.2 lbs.; the height to which it was raised was (42 fath. 2 ft. 6 in.+37 fath. 5 ft. 6 in.+8 fath. 5 ft. 6 in.)=535 ft. 6 in.; the weight multiplied by the height in feet, is equal to 102,721,-323 lbs. of water lifted one foot high with 94 lbs. of coal.

This result, however, although it shows how much water was actually raised to the surface, does not show the duty of the engine; for although, in consequence of leaks and defective valves, the quantity raised is not so great as it would be were it possible to have every part perfect, nevertheless, the engine has to raise the quantity due to the areas of the pumps, multiplied by the length of the stroke, under the pressures due to the columns of water equal in height to the lifts, notwithstanding that, in consequence of the defects mentioned, the whole quantity may not reach the surface; the fair mode, therefore, of calculating the duty of the engine, during the trial, would be as follows:

Weight of column of water, 11 inches diam., and 42 fath. 2 ft. 6 in., or 254.5 feet high,	10,498 lbs.
Do do 11 inches diam., and 37 fath. 5 ft. 6 in., or 227.5 feet high,	9,384 lbs.
Do do 10 inches diam., 8 fath. 5 ft. 6 in., or 52.5 feet high,	1,824 lbs.
Load upon engine,	21,706 lbs.

21,706 × 672 strokes × stroke $8\frac{1}{12}$ feet, =117,906,992 lbs. weight, lifted one foot high with 94 lbs. of coal.

"From the foregoing, it will be seen that 191,823 lbs. of water were raised 535 feet 6 inches high, with the expenditure of 94 lbs. of coals; and that the duty of the engine was

equal to nearly one hundred and eighteen millions of pounds raised one foot high. I should observe that the engine had not been overhauled, or any thing done to it to prepare for the trial, which was not determined upon (as regarded the engine upon which the trial was to be made) until the previous day. The boiler and flues had not been cleaned for eleven months. My object was to prove what could be done by an engine worked upon the expansive principle, and I therefore considered that a trial for two hours would prove the capability of the engine, although, most probably, the average duty of the engine for twelve months, would not be so great as it was for the short time that it was under trial. I am perfectly satisfied the trial was a fair one.

"I was not able to ascertain what the pressure of steam was when it first entered the cylinder, having no indicator with me; but the engineer, Mr. West, stated that the steam was wire-drawn, and reduced from 40 lbs. above the atmosphere, (which was the pressure in the boiler) to 30 lbs. above the atmosphere, upon entering the cylinder.

"The steam was cut off at one-sixth the stroke. The steam in the jacket round the cylinder communicates directly with the boiler, and radiation is completely prevented by the casing round the jacket; consequently, a high temperature is preserved, which is absolutely necessary to obtain the full effect from the expansive force of the steam.

"The following will show what effect could have been produced by the steam power, provided the engine and pump gear had worked *without* friction:

Pressure of steam when first admitted into the cylinder, (30 lbs.+14.75 lbs.—1.5 for imperfect vacuum)=43.25 pounds.

For $\frac{1}{6}$ of the stroke, the pressure was per sqr. inch, 43.250 lbs.

When the piston had made $\frac{2}{6}$ of its stroke, the pressure was reduced to 21.625 "

Do $\frac{3}{6}$ 14.416 "

Do $\frac{4}{6}$ 10.812 "

Do $\frac{5}{6}$ 8.650 "

Do $\frac{6}{6}$ 7.208 "

6)105.961 "

Mean pressure of steam, 17.66 lbs.

The area of cylinder was 1963.5 square inches.
Mean pressure of steam per sqr. inch, 17.66 lbs.
Number of strokes, 672
Length of stroke in cylinder, 9 ft. 1 inch.
(being one foot longer than in shaft.)

Power of steam, 1963.5 square inches × 17.66 lbs. per square inch, × 672 strokes × $9\frac{1}{12}$, length of stroke, = 211,658,-702 lbs. raised one foot high with 94 lbs. of coals; and now, as the effect produced was 117,906,992, the friction of the machinery was equal to 93,751,710 lbs. raised one foot high, or about $7\frac{3}{4}$ lbs. pressure per square inch. As the friction of a water works pumping engine is about $5\frac{3}{4}$ lbs. per square inch, it may be safely inferred that an engine, when working on the expansive principle, at a water works, will do more work than it does in the mines. To those who have seen the heavy pump-rods, balance-bobs, &c., attached to a mining engine, it will appear very evident.

In the observations I have had opportunities of making, I am very well satisfied that the engine I am about to erect at the East London Water Works, will do a duty equal to at least one hundred and twenty millions lbs."

From the foregoing we plainly see the economy—or rather trifling cost of work done—as far as the mere fact of raising water is concerned. We will now continue with Mr. Wicksteed's

paper, and see if any beneficial effects are apparent when using high expansive steam in a double acting rotative engine :

" As it had been observed that the expansive principle would not answer for rotary or double engines, I was induced to make some observations on a double engine, working the stamps for breaking the copper ores, at the Tincroft mines, and I beg leave to give you the details :

The diameter of cylinder,	36 inches.
Length of stroke,	9 feet.
Length of crank,	3 " 6 "
Steam was cut off in down stroke, at	$\frac{1}{5}$
Do up stroke, at	$\frac{2}{3}$
Number of strokes per minute,	10

" The engine worked with a very equal velocity ; in fact, there appeared no irregularity whatever in the motion. Capt. Paul, the agent of the mine, allowed me to examine the coal accounts, from which it appeared that the average consumption of coals for the engine was 30 bushels for 24 hours.

The engine was working—1st, a set of stamps; 2d, a pump ; 3d, a crushing machine ; and 4th, a trunking machine. The last two pieces of machinery had lately been added ; and previous to this increase of machinery, it appeared from the books, that the consumption of coals was equal to 27 bushels, of 93 lbs. each, in 24 hours.

" The stamping machinery worked 48 lifters; to ascertain the weight of them, I examined an account showing the weight of 26 of the cast iron heads, when new, and found the average weight to be 3 cwt. 12 lbs. each ; these are used until the weight by wear is reduced to 1 cwt. 2 qrs.; the average weight will therefore be (3 cwt. 12 lbs.+1 cwt. 2 qrs.÷2) = 2 cwt. 1 qr. 6 lbs. The weight of the wood-work of the lifter, the iron straps, washers, &c., I found by trial to be 1 cwt. 3 qrs. 24 lbs., making the total average weight of the lifter and head (2 cwt. 1 qr. 6 lbs.+1 cwt. 3 qrs. 24 lbs.)=4 cwt. 1 qr. 2 lbs., or 478 lbs. The average height the stamps were lifted was 10 inches, and the 48 stamps were lifted five times per stroke.

"The following calculations will show the duty performed by the stamping engine :

Forty-eight lifters×478 lbs.×0.833 feet, height lifted,×5 times per stroke×10 strokes per minute×60 minutes per hour×24 hours per diem = 1,376,089,344 lbs., lifted one foot high in 24 hours.

The diameter of the pump was 14 in., or 1.069 sqr. ft. area.

Length of stroke,	6 feet.
Strokes per minute,	10
Lift,	26 feet.

Duty Performed—1.069 sqr. ft.×6 ft.×62½×lbs per cubic foot×26 feet lift×10 strokes per minute×60 minutes×24 hours = 150,087,600 lbs., raised 1 foot high in 24 hours.

Duty of Engine—1,376,089,344+150,087,600÷27 bushels = 56,525,072 lbs. lifted one foot high with a bushel, or 93 lbs. of coals.

"The single engine at the Holmbush Mine was, during the time of my experiment, doing the work of 26.48 horses. Thus, the experiment lasted 2¼ hours, or 135 minutes,×33,000 lbs. lifted 1 foot = 4,455,000 lbs., which would be lifted 1 foot high by the exertion of one horse's power in 2¼ hours; 117,906,-992 lbs.÷4,455,000 = 26.48 horses' power. The coals consumed were equal to 94 lbs., or (94÷26.48÷2.25 hours) = 1.57 lbs. of coals per horse power per hour. The coals used by one of the pumping engines at Old Ford, in an experiment lasting one hour, tried upon the 18th February, 1835, were equal to 4.82 lbs. per hour per horse power, or three times the consumption of the Cornish engine, notwithstanding the extra friction in a pumping engine.

"The double engine at the Tincroft Mines was doing the work of 32.11 horses. Thus, 33,000×60 minutes×24 hours = 47,520,000 lbs., lifted 1 foot high by the exertion of one horse power during the 24 hours. The engine lifted 1,526,176,944 lbs. 1 foot high in the 24 hours; 1,526,176,944÷47,520,000 =

32.11 horses' power. The coals consumed were 27 bushels, of 93 lbs. each, or 2511 lbs.÷24 = 104.62 lbs. per hour÷32.11 horses' power= 3.25 lbs. of coals per hour per horse's power.

"Mr. Farey, in his valuable treatise on the Steam Engine, states that a rotary or double engine of Bolton and Watt's construction, will require $10\frac{1}{2}$ lbs. of coals per hour per horse's power, or three times the consumption of the Tincroft double engine."

93. The following tables may prove interesting. The first is a chronological table, exhibiting the gradual improvement of the steam engine (as applied to working mines) in the course of sixty-six years. The second table exhibits the average duty performed by the engines in Cornwall, in 1835 and 1836, including old and new engines, and all sizes.

TABLE XI.

Date.	lbs. raised 1 foot high, with the consumption of 1 bushel or 94 lbs. of coal.	lbs. of coal per hour, per horse power.
1769	5,590,000	33.33
1772	9,450,000	19.70
1786 to 1800	20,000,000	9.30
1813	28,000,000	6.64
1814	34,000,000	5.47
1815	50,000,000	3.72
1825	54,000,000	3.44
1827	62,000,000	3.
1828	80,000,000	2.32
1834	90,000,000	2.06
1836	97,000,000	1.91
Trial of Fowey Consol's Engine, in 1835	125,000,000	1.48

The above table was compiled by Mr. John Taylor, an authority that cannot be disputed, from authentic accounts procured by himself in Cornwall.

TABLE XII.

No. of Eng's.	Diam. of cylinder.	Average lbs. raised 1 foot with 94lbs. of coal.	Av. load on piston, p. square inch.	Average number of strokes p. minute.	Highest duty in lbs., raised 1 foot with 94 lbs. coal.	Lowest duty in lbs., raised 1 foot with 94 lbs. coal.	Time of working, in months
4	90	47,829,830	8.971	6.707	61,884,427	35,775,624	22
3	85	71,146,686	11.643	5.761	77,311,413	63,172,606	17
7	80	66,044,570	10.989	5.351	97,595,571	37,059,128	18
2	76	47,685,167	12.594	5.071	65,345,407	40,457,463	22
5	70	52,009,587	9.672	5.416	81,026,642	22,313,025	20
3	66	49,734,514	7.965	5.379	77,446,214	24,277,768	20
2	65	54,921,572	14.57	3.098	63,411,060	43,126,101	22
1	64	50,107,225	10.74	5.83	39,625,677	19,344,343	17
6	60	48,656,046	10.819	5.73	76,673,995	29,233,376	18
1	58	61,317,268	12.29	.945	67,115,413	55,366,495	12
1	56	38,059,440	12.826	3.452	46,509,910	30,656,541	8
1	53	44,468,465	16.	2.895	58,624,253	40,294,578	6
6	50	43,645,480	9.898	5.075	60,723,738	31,587,345	18
1	45	48,137,083	18.35	6.137	55,564,549	41,268,911	8
1	42	40,712,991	16.199	8.667	46,132,677	36,499,814	23
1	41	49,052,474	16.228	5.884	57,288,816	42,081,037	22
6	40	45,591,848	11.196	5.356	64,400,208	24,962,485	12
1	39	31,286,192	11.451	3.13	39,427,731	25,395,105	23
9	36	33,277,832	12.781	6.357	47,884,690	17,619,529	13
1	33	30,245,394	15.927	6.4	36,265,146	22,938,142	23
4	30	38,828,948	13.838	7.039	74,897,208	19,344,343	17
1	26	31,529,396	17.56	8.26	34,943,591	27,697,031	14
1	25½	28,248,292	17.6	11.555	32,431,160	20,773,914	23
3	24	35,377,387	13.682		47,101,689	20,562,859	21

"I cannot conclude this paper without acknowledging the great attention I received from the intelligent engineers and captains of the mines in Cornwall, whom I found, as in my former visit, most anxious to give every facility to those parties who visit the county for the purpose of obtaining information; and notwithstanding their own thorough conviction of the advantages of the system they adopt, and of the truth of the statements made in the monthly reports, they were in every instance most desirous of removing the doubts that others might have, by permitting any trials to be made, and by most readily and openly giving any information that might be required.

"THOMAS WICKSTEED.

"Old Ford, Aug. 7, 1837."

94. As to the actual economy, we would merely call attention to the following statement of the gross quantity of water raised by three different Cornish engines, one foot high, for the expense of one farthing sterling, viz:

Huel Towan—Wilson's engine, 1,085 tons;
Binner Downs—Swan's engine, 1,006 "
East Crinnis—Hudson's engine, 870 "

The above, and similar statements, caused the unbelief of the London engineers; and, at first sight, it does certainly appear an almost incredible amount of work; but a careful perusal of Mr. Wicksteed's paper will surely satisfy any person who will take the pains to examine the merits of the case.

95. For fear, however, that there may be some who still hesitate, we will insert a short account of an experiment made on low pressure steam, by the above named gentleman:

"On the 18th of February last (1835), I tried the power of an engine on this construction (similar to the engine, plate 5). The experiment lasted one hour, and 469 lbs. of good Holywell Main large coals were used. The diameter of cylinder was 60 inches; length of stroke, 7 feet 9 inches; the engine made 869 strokes in the hour, or 14.48 per minute; the pressure of steam was $2\frac{1}{2}$ lbs. per square inch above the pressure of the atmosphere, which was $14\frac{3}{4}$ lbs.; the vacuum in the condenser, $13\frac{1}{4}$ lbs.; the diameter of the pump was 27 inches; the length of the stroke, 7 feet 9 inches; the pressure upon the pump piston was equal to a column of water 115 feet in height; load upon pump piston, 28,577 lbs., equal to 10.1 lbs. pressure per square inch of the steam piston; as the pressure of the steam, minus $1\frac{1}{2}$ lbs. for imperfect vacuum in the condenser, was $15\frac{3}{4}$ lbs., the friction of the engine must have amounted to 5.65 lbs. per square inch.

"The steam used in the hour may be found thus:—the area of cylinder was 19.63 square feet, and the steam was cut off at 1 foot 3 inches from the end of stroke, making the length of stroke for the dense steam 6 feet 6 inches, which multiplied by the area, gives 127.6 cubic feet per stroke; add $\frac{1}{10}$ for loss of

steam per stroke in the vacancies of the cylinder, making a total of about 140 cubic feet of steam per stroke; which, multiplied by the number of strokes per hour (869 × 140), is equal to 121,640 cubic feet of steam, generated under a pressure of 35.2 inches of mercury, at a temperature of about 222° Fahrenheit.

"The "duty" performed was 34,467,052 lbs. raised one foot high, with a bushel or 84 lbs. of coals.

"The power of the engine during the time of trial was (28,577 lbs. load × 7.75 stroke × 14.48 strokes per minute ÷ 33,000) equal to 97.2 horses' power.

"The steam used was 1251 cubic feet per horse power, to produce which, at a temperature of 222° Fahrenheit, would require about 0.856 cubic feet of water; and to convert this quantity of water into steam at 222°, it *required* 4.82 lbs. of coals."

96. Having thus seen the utility of this system, as practised in Cornwall, it will be desirable to exhibit its beneficial effects here also, as it is used in the steamboats on the North River. To enable the reader, therefore, to make comparisons himself, the following table has been carefully compiled; giving, 1st, the requisite dimensions; 2d, the cut-off; 3d, the pressure of the steam; 4th, the quantity of fuel consumed; 5th, the amount of work done; 6th, the time of doing the work of several of the most celebrated boats on the river. For particular descriptions of engines, with their working parts, the reader is referred to the tabular statement and explanation of the plates at the end of the volume.

97. *Steamboats of the West.*—Having thus considered the steam engine as used on the Eastern Rivers of the Union, we will proceed to notice the peculiar construction and principle of those used on the Western waters; and for the purpose of better enabling the reader to understand the beauty of the arrangement of these machines, it will be well briefly to point out the difficulties to be overcome in the navigation of the mighty rivers of that vast country.

98. From the size and rapidity of these waters, the ordinary

method of sails, or oars, is utterly inadequate to produce any useful effect in stemming the current.

99. The produce and manufactures of the upper states, are, however, readily conveyed down to New-Orleans, by means of enormous flat-bottomed boats, formed by combining large timbers together, and thus making a superior kind of raft, which, when unloaded at New-Orleans, are broken up and sold; the timber of which they were formed having suffered but very little damage from its voyage down the river. These flats are continually coming down the river; the persons who navigate them have to return, nevertheless, which they would find a very fatiguing voyage indeed, if they had no steamboats; adding to this, the enormous traffic required to supply the upper states, nearly all of which passes through New-Orleans, the reader will readily imagine the importance of having an upward as well as a downward navigation. Oars and sails failing, some other means had to be tried; the steam engine, then, just coming into use, was employed; and from the fact that the same engine may be made to work at any speed, and almost with any power, its utility was at once established. We will now consider the obstacles to be overcome.

100. In the first place, at certain seasons of the year the rivers are usually so low, as to have only three or four feet of water.

Secondly, in some parts of the rivers the channel is so confined, as to render the current very rapid.

Thirdly, in many parts the stream is so slight, as to be really of no importance.

101. To overcome the first difficulty, it was necessary that the boat should draw very little water; the second, that the engine should be very powerful; the third, that the engine should be readily reduced from a greater to a lesser power; for if it were not so, there would occur a very great waste of power or fuel, and consequently a very considerably increased and unnecessary expense. Such, then, being the obstacles, we will consider the means used to overcome them.

102. The vessels are built to draw from two to four feet of water, and of such beam and length as the nature of their cargoes demand. The general dimensions are as follows; namely, extreme length 150 feet; breadth of beam 20 feet; draught of water 3 feet. They are capable of accommodating from 200 to 400 passengers, besides carrying several hundred bales of cotton, and other goods.

103. More expense has been incurred, and time and ability employed in bringing to perfection the model of these boats, than has probably been expended on any other kind of vessel in the United States.

104. The engines are very strong and carefully made, although there is no great amount of bright work about them. They are placed either horizontally, or at an angle tending upwards to the centre of the paddle wheel shaft.

105. The boilers are of small dimensions, but many in number; they are nearly always cylindrical on account of their required strength, and also to save room; and because when any increase or diminution of power is required, any one or two can be attached to, or detached from the engine at pleasure, by means of cocks and valves arranged for the purpose.

106. The steam is used expansively, as being most economical in every point of view; and, in the methods adopted to do that most effectively, great ingenuity and skill have been manifested.

107. The dangers to be apprehended in navigating these waters, of running aground, and meeting sudden shocks, have to be guarded against as much as possible; the sudden stopping of the paddle wheel has to be expected, and to meet that circumstance, as well as for economy, the connecting rod is made of pine wood.

108. From the enormous pressure at which the steam is used, the ordinary valves and methods of working them would absorb too much power, consequently a very simple and effect-

ive arrangement has been introduced, by means of which it is rendered easy and rapid.

109. As the quantity of water evaporated is very great, so is the quantity of fuel consumed great in proportion; to save, therefore, as much as possible, the exhausted steam is suffered to escape through a copper vessel or chimney, called a "coughing box," where it deposits a portion of its caloric, which is taken up by the water for the feed, which surrounds it, and which is then passed on to the boiler.

110. The speed of these boats varies from 8 to 15 miles an hour in ascending the rivers, and frequently, when going down to New-Orleans, nearly doubles the latter speed, the average being 18 miles.

111. The actual occasion of the serious accidents which have occurred on these waters, is owing to three or more causes, of which we will place,

First, the striking of snags or sawyers; 2d, the insufficiency of the engines; 3d, the fact of the captain having undisputed authority over the engine, and all connected therewith; 4th, the inability of the boilers to bear the pressure that the caprice of the captain, or ignorance and neglect of the engineer charges them with.

Divest these boats of the three last causes, and they would equal, if not surpass, in safety, any boats with low pressure or condensing engines in these or any other waters.

CHAPTER II.

PADDLE WHEELS.

112. As the effective value of the marine steam engine is intimately connected with the form and dimensions of the paddle wheel, we purpose, in this part of the work, to say a few words on the subject.

113. Notwithstanding the fact that the common paddle wheel was decidedly the first adaptation of any kind attached to vessels for the purpose of propelling them through the water (and from the close affinity existing between the old undershot water wheel and its performances, and the desired effect required in propelling vessels, it appears obvious that such should have been the case); nevertheless, engineers and speculators not only doubted the possibility of the common paddle being effective, but actually laid it aside as altogether useless, because the steam engine itself was so inefficient as to be unable to cause the vessel to advance at all, except at such speeds as rendered the application of steam power to navigation altogether of no value.

114. For such reasons, the paddle wheel was condemned as useless; and the ingenuity of the curious was busily engaged in attempting to find out or adopt some other means for attaining the same end.

115. An intelligent Frenchman copied the very beautiful action of the 'duck's foot,' collapsing when drawn forward, and expanding when pushed back. Another individual applied paddles vertically to the sides of the vessel, acting similarly to those used by the Indian in propelling his canoe. Another had a series of float-boards attached to a beam, which

were drawn through the water, raised, carried forward, depressed, and again drawn back. Again, the idea of driving water in at the bow of the vessel, and forcing it violently out at the stern, by means of a pump or pumps, occupied the public attention for some time ; this scheme was also soon abandoned. Many other plans were successively tried, which it would be useless here to enumerate ; it must be acknowledged, however, to the credit of the inventors, that all these various contrivances performed their duty, but at a speed so slow as to be discarded and thrown aside nearly as soon as they were completed.

116. There have been, however, one or two adaptations introduced within the last few years, which have attracted more attention than any of the former ones ; namely, the screw propeller, and the chain and drum. The former consists of a screw, similar to that ascribed to Archimedes, placed horizontally in a chamber in the bottom of the boat or vessel, which is caused to revolve by means of gearing worked by a steam engine, and so worms the water through it ; thus causing the vessel to advance without creating the back-water and undulations produced by the paddle wheel. The latter plan is to have a continuous chain laid along the bottom of the canal, which is passed round a drum on board the vessel, and again let down through a hawse pipe at the stern ; thus, upon the drum being caused to revolve, the vessel is drawn forward. These two plans, however, are more adapted for canal navigation, where the undulation of the water which would be caused by the use of paddle wheels is so very injurious to the banks, than for any other kind of navigation, in which the paddle wheel is most certainly more efficacious than any other combination yet in operation.

117. The revival of the paddle wheel, and consequently almost the actual existence of the steamboat, at least at so early a date as it did come into use, was owing to the unprejudiced and energetic mind of the elder Stevens ; who, when trying his experiments, was requested by one of his men, to make use

of a wheel similar to the common water wheel, which he, amongst the rest, imagined much too simple an apparatus to effect such a purpose. He did, however, try the plan, and as it certainly answered his views better than any other contrivance, it was forthwith applied to boats by himself and others.

118. The credit of this, however, still remains with the family; and Mr. R. L. Stevens, one of the sons, has, within the last few years, considerably improved the paddle wheels; which improvement is now in general use throughout the United States and elsewhere. It should here be remarked, that the steam engine has been considerably improved in the meantime.

119. The first wheel used was a simple wheel with buckets or float-boards, radiating from the centre, and extending across the whole width of the wheel, in a direction parallel to the shaft or axle.

120. In the next, the floats were so arranged as to enter the water rather more at a right angle; this plan was soon condemned, as the wheel had a natural tendency to raise the water. The floats were again altered, and they were placed diagonally, instead of directly, across the width of the wheel. All these changes were for the purpose of obviating or removing, if possible, the bad effects of the back water and wave caused by the common float, which materially retarded the speed of the vessel; still the object was only partially gained. At this time, as before stated, Mr. R. L. Stevens applied his mind to remedy this evil, and he consequently introduced the *split bucket*, now so much used; how far he succeeded in accomplishing his object may be readily seen, by observing the great difference between the action of his wheels and others on the old plan, upon the water.

121. The paddle wheels of the new 'North America' are on this construction, (of which plate 27 represents one,) with the method of attaching the buckets or float-board.

122. The subject of paddle-wheels, and the desire to overcome the above mentioned objections to the use thereof, at least in their original form, has occupied no little of the time of Eu-

ropean engineers during the last few years. Many patents have consequently been taken out, for combinations tending to this desired end; but, generally, the great expense attending their outfit, and very great liability to derangement, have confined their use to experimental vessels not adapted to ocean navigation. Morgan's patent paddle wheel, which is one of the best, has been successfully applied to some of the British steam vessels of war; their expense, however, and their complication has deterred most materially their introduction into general use.

123. It had now become obviously a great desideratum to arrange such a wheel as should obviate the original objection to paddle wheels, without incurring the objections to Morgan's wheel. Mr. Joshua Field, the celebrated English engineer, undertook, in consequence, a series of experiments on the comparative value of different arrangements, into which he entered with great accuracy and care, and the result he has embodied in what he terms the "Cycloidal Paddle Wheel." Such is the wheel which he applied to the 'Great Western' steam ship, now trading between this port and Bristol, and which is also applied to the steam ship 'British Queen,' between London and this port. This wheel, for ocean navigation, bears superiority over all others; as from its form it takes the water gradually, and, from the narrowness of each float-board, it lifts little or none; making, in consequence, a very small wave when compared to the old bucket wheel.

PART IV.

LOCOMOTION.

LOCOMOTION.

124. The application of steam to the purposes of locomotion has been attended with the most beneficial effects. Obstacles which, a short time ago, appeared insurmountable, have been overcome; economy in construction and use has been studied, and speed and durability obtained. As a proof of this, we extract from a circular, published by Mr. W. Norris, of Philadelphia, the following letter, which shows that the monstrous amount of money expended in repairing the engines on the Manchester and Liverpool Rail-Way may be saved to the Company, whilst the amount of work done shall in no way decrease:

Certificate.—"I have been in the employ of the State of Pennsylvania, as Locomotive Engineer, for nearly two years; and had in my charge the locomotive 'Lafayette,' made by William Norris, for five months and three days. She performed regularly each and every day (except four days), with full trains, very frequently thirty-eight cars. This engine never lost a trip, and the whole cost of repairs for the five months and three days, did not amount to one dollar.

"(Signed,) JOHN DONAHOE."

125. When we look back, and examine the crude attempts of the mechanics thirty years ago, to adapt the power of steam to the purposes of locomotion, we are apt to smile; but we should never for a moment forget, that it is to such individuals and their extraordinary exertions, that we owe the benefits we are now enjoying. Nor should the fact that these were chiefly self-taught men—men who had none of those advantages which are attainable now, by the poorest labourer as well as by the wealthiest merchant, the advantages of learning and education—men who had to earn their bread by the sweat of their brow,

as well as try out their experiments. The veriest novice of the present day can converse fluently upon subjects that were then unknown, or if known, only to a very few; and when any account of these matters was promulgated, they came forth, not in the simple terms of common arithmetic, but dressed in the garb of algebraic formulæ. These documents, to the plain mechanic, were consequently comparatively valueless; and the only person, perhaps, able to judge and appreciate the value of the matter they contained, was debarred all access and acquaintance with it.

126. We are glad to see that writers on scientific subjects are now reducing their formulæ to such terms and expressions as are intelligible, not only to the learned of the earth, but to the simple ones, and the consequent advantages are becoming daily more apparent.

127. For, how long did the notion prevail, that an engine was incapable of advancing on a rail-way, unless through the intervention of a wheel and rack, or propellers, which were to act like feet, at the back of the machine, and push it forward? What numberless patents were taken out, and models made, showing the beauty and convenience of each arrangement? Could the gentleman who invented and patented the locomotive engine, which, to this day probably, brings its trains of coal wagons into the town of Leeds—and the extraordinary man who manufactured, and, in all human probability, arranged the machine—see the locomotive engines which have been sent out from the same shop within the last few years,—imagination may picture, but words cannot pourtray, their intense surprise, when, instead of the massive machine such as they devised, they see the comparatively light and fragile locomotive of the present day; its four wheels turned and polished on their tires, as if the slightest roughness would retard its progress, and as capable of going fifty miles per hour with its load as at the slower speed of seven and a half; which is the greatest, I believe, that the old machine can perform with safety.

128. Had Matthew Murray received the advantages now at-

tainable by every one, to what might not he have arrived? The mind that was sufficient to apply the eccentric wheel and slide to the steam engine, if stored with the experiments and learning of the well educated and informed of other nations, might have arranged and built a machine such as we, with all our learning, have not been able yet to do. But to recur; until accident stepped in and pointed out the connection between the gravity of the engine and the friction of the wheel on the rail, hardly any one believed in its existence. The philosophers of the day laughed at it; argued and experimentalized on the subject, and the fact was nearly being committed to the storehouse of nature, to be preserved for another generation who might possess clearer perception than ourselves. Such, however, was not the fact. It was received with jealousy and doubt at first, we must admit; nay, it is at the present day looked on with suspicion, though we have such facts as the following to prove its truth:

129. The steam engine 'George Washington,' made by Norris, of Philadelphia, ascended an inclined plane with a rise of one foot in fourteen, with a load of 19,200 lbs., at the rate of fifteen and a half miles an hour; the engine weighing 14,930 lbs. only.

130. This, it must be remembered, was not the result of fortuitous circumstances, but what the engine could perform during a week as well as during the two minutes and one second she was about it. The steam was 60 lbs. on the inch. This fact was witnessed by numbers of gentlemen, who can all give evidence of its truth. Here, then, is rather a severe blow to the philosophers. But here is also a proof of the benefits arising from a knowledge of cause and effect; the result of which is the fact that, where the engine is so arranged as to have as much weight as possible on the driving wheels without increasing the actual weight of the machine, the best effect is produced. But these facts, as well as hundreds more, were hidden from our elder brethren of the profession; it becomes us, therefore, not to see them now overlooked.

131. The great advantage which results from rapid communication has called into operation the inventive talents of all nations. The science of mechanics is not now as firmly confined to the classes who gain their bread by its pursuit, but is followed up with ardour and enthusiasm by men of education, ability and wealth. So far has the benefit of its study progressed, that any one ignorant of its principles and rules is hardly considered to have received a liberal education. And to what result does this study of mechanics—some sceptic may advance—to what good does it tend? We answer boldly, to the benefit of the whole human family; in the increase of wealth, happiness and comfort.

132. The man of leisure, instead of wasting his time in idleness, now occupies himself in trying to improve what has been already done, or in inventing new methods for obtaining the same ends. And, whilst the mechanic is toiling at his bench, he is in study, arranging and scheming new work for him. It is to such men as these that a country is indebted. More is due to such men as Stevens, Fulton, and Evans, than is recorded as having been paid to the Roman generals on their return from a successful campaign. Time and wealth have been disregarded in making our steamboats and rail-roads, the most convenient and speedy in the world; private and temporary interest have been set aside for public good, and the permanent benefit to all is large.

133. The first successful manufacturer of locomotive engines in the United States was Mr. M. W. Baldwin, of Philadelphia; who, about the year 1829, commenced by making a small model of an engine, not very unlike the arrangement of Messrs. Braithwaite and Erickson's engine, the 'Novelty,' which so ably contested with Mr. Stephenson's engine for the prize, on the Manchester and Liverpool Rail-Way, on its first opening.

134. Soon after this, Mr. Baldwin constructed the first locomotive for the Germantown and Philadelphia Rail-Road, now called the 'Old Ironsides,' which engine was the first (having

her cylinders on the outside of the smoke-box) that had been manufactured in the United States. This circumstance, at the time, caused much ridicule and many remarks to be passed on the manufacturer. Time, however, has abundantly proved the folly of those persons, and the correct views of Mr. Baldwin; all manufacturers having since that time placed their cylinders outside—thus copying the very plan they had formerly derided.

135. About this time a locomotive engine was sent from the West Point foundry for the same road, which was not successful. Some engines were also sent from the same place to the Mohawk Rail-Road, which, after being altered by Mr. David Matthews, answered very well.

136. A difficulty now occurred which threatened to injure the benefits arising from travelling by steam, if not to remove them altogether, namely: the engines which had been imported were, from the complicated form of their working parts, the number of bearings which occurred, and their consequent liability to get out of repair, nearly all very soon out of working order. This occurred in a measure from the nature of the roads, and from the curves on the line being in many cases of such short radii, that the engines on four wheels could not work round them without actually jumping, at every yard or so, from the flange of the front wheel riding on the rail. This circumstance attracting the attention of Mr. David Matthews, he immediately suggested and applied the truck frame, which is attached to the locomotive engines, (plates 43, 47, 48,) which, moving on a centre pin, and the wheels not being far apart, suits itself to any curve that may occur; thus enabling the engines to go round without any danger or difficulty. So beneficial is this arrangement of Mr. Matthews, that the English manufacturers are now using it, affording ample proof of its efficacy.

137. From this time, Mr. Baldwin and some others were carrying on a very extensive trade in the manufacture of locomotive engines, in supplying the rail-roads throughout the Union as fast as they were prepared to use them. Their great

success induced Mr. Norris, of Philadelphia, to embark in the same business, he being very anxious that our machines should equal, if not surpass, the English engines in their performances. To this end, he advanced a considerable sum of money to assist Col. Long, of the U. S. Engineers, in his project of building a locomotive engine.

138. The first attempt had a boiler shaped in front like the bows of a boat, to enable it to cut through the air with less difficulty than if the end had been flat, as they are made at present; the boiler had two return flues. The cylinders and other parts were sufficiently effective, but the boiler was a complete failure; the gentleman not being so familiar with civil engineering as to know that on the efficacy of the boiler depends almost entirely the value of the working power of the engine.

139. After spending much time and money in trying experiments, and projecting new ideas, he finally abandoned the undertaking, having fully satisfied himself and Mr. Norris of his inability to perform the task. Mr. Norris, however, though much disappointed, and nearly exhausted as to pecuniary means, still persevered, and by good fortune, meeting with Mr. F. D. Sanno, an intelligent and clear-headed mechanic, forthwith engaged his services.

140. Mr. Sanno, being sensible of the necessary provisions for such a machine, set to work and made a new boiler; he however used the old cylinders, and some other parts, and finally turned out a new machine. With this engine, Mr. Sanno had often boasted that he would ascend the Columbia inclined plane on the Pennsylvania State Road, a few miles from Philadelphia; and this assertion he made long before he had finished the engine. He was of course openly laughed at; but, as in a former case, the ridicule returned on the heads of those who sent it. For, one morning in the month of July, 1836, the first trial that had been made with the engine, Mr. Sanno, and two or three of the workmen, got the steam up, and proceeded from Mr. Norris' works to the top of the inclined plane, which they ascended without hindrance or difficulty.

141. Mr. Norris having thus established a name for the manufacture of locomotive engines, soon had his shops full of work; and, under the careful superintendence of Mr. Sanno, he is certain to meet with that success his enterprising conduct so justly deserves.

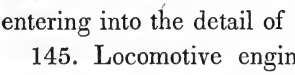
142. During the year 1839, the regular delivery was one locomotive engine per week; an amount of work which exceeds that of any other establishment in the United States.

143. Many very beautiful and effective engines have been made since Mr. Baldwin commenced, far exceeding in their power and economy the utmost expectations of their inventors, amongst whom are Messrs. Rogers, Ketchum, and Grosvenor, of Paterson, New-Jersey; Messrs. Harrison and Eastwick, of Philadelphia; Dunham, of New-York, and many others.

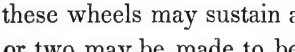
144. In considering the power and arrangement of a locomotive steam engine, we shall have to take into account a circumstance which does not enter into the calculations for a land engine—that is to say, weight; for, as upon its weight and the arrangement thereof, the power of the engine materially rests, it will be well to consider this subject a little maturely before entering into the detail of the engine.

145. Locomotive engines have four, six, or eight wheels; two or more of which are attached to the engine. Each one of these wheels may sustain an equal portion of the entire weight, or two may be made to bear the greater part, and the weight may then be divided amongst the rest.

146. It is well known that if a weight W be suspended from a point C, on a bar A B, which is equidistant from A and B,



half of the weight will be sustained at A, and the balance at B; but if the weight W be moved, as shown below, to another point D, which is one quarter of the whole length from B, then B will sustain three parts, and A only one. Supposing, therefore, that the line A B represents the frame of a locomotive steam engine, every alteration in the position of the wheels will make a cor-



responding alteration in the effective power of the machine; for consequent upon its weight is the adhesion of the wheels to the rails. The skilful adjustment of this weight seems to have escaped the earlier manufacturers of locomotives. The great attention which this circumstance now receives, has produced such machines as the one already alluded to. Having thus seen the effect the weight exerts, we will proceed to other matters. First in importance, therefore, is the boiler, its form, capacity, and generating surface.

147. Pambour, in his work on Locomotion, says that the present form of boiler belongs to a French gentleman, of the name of Seguin. It matters little to us who was the real inventor, though at the same time we are desirous of awarding to each his due. Therefore, whether William Booth or Seguin invented the same, we certainly use it, and are fully sensible of its decided superiority over every other arrangement for the same purpose.

148. *Fire Boxes.*—The size and extent of the fire boxes is another circumstance to be considered; no decisive rule, however, having been yet given, we can only set before the reader statements of the dimensions of the various locomotives which we have examined; and from these facts he will be enabled to deduce such dimensions as will correspond to the arrangements which produce the best effects.

149. *For Table of Dimensions of Fire-Boxes, &c.* see the end of this work.

150. *Tubes.* Upon the number of tubes in the boiler much of its power depends; the greater the number of tubes, the greater surface of water will be exposed to the action of the fire. In the American engines, a greater number of tubes are used than in the European; this circumstance alone gives us an advantage.

151. *Chimney.*—The dimensions of the chimney should be considered in connexion with the area of fire grate, and the quality of fuel used. The chimnies of some locomotives im-

ported from England have been reduced from 14 to 10 inches diameter, and with good effect.

152. *Fire Grate.*—Upon the area of fire grate and generating surface, the capabilities of the boiler depend; and if the boiler cannot supply considerably more steam than is required, the least extraordinary exertion will prove its inefficacy; the dimensions, therefore, or capacity of the cylinder must be considered, in estimating the number of tubes and area of generating surface, as well as the area of grate.

153. *Blast Pipe.*—The arrangement of the blast pipe, as regards its admission into the chimney, is another point to which attention must be called; for upon its position will depend the value of the application. We have found by experience, that the higher the pipe is carried up the chimney, the less the power of the draught, and also that any openings in the smoke box are very objectionable. The blast pipe is now admitted only half an inch above the top of the smoke box, and the increase of draught is found to be very great in consequence.

154. *Cylinders.*—The cylinders are fixed to the outside of the smoke box, and are placed at an angle suited to the dimensions of the driving wheels. The difference between these and the English consist in our ports or steam openings being larger, and our waste or eduction passage less cramped.

155. *Valve.*—The valves are much the same, only their capacity for the egress of steam is greater.

156. *Valve Rods.*—Instead of the complicated machinery which occurs in Stephenson's patent locomotive, and which from its confined position is difficult of access, the eccentrics are placed outside the frame. (See the plate of the locomotive 'Juno.') The tumbling shaft is attached to the under side of the frame, and from the eccentric to the slide only three pins occur where the motion is changed. The handle raises the one eccentric rod and drops the other.

157. *Connecting Rod.*—The connecting rods, instead of being 36 or only 42 inches long, are produced to 8 feet 2 inches, which not only reduces the friction on the guides most materially,

but also naturally alters the position of the driving wheels, and enables us to have as much as possible of the whole weight on them.

158. *Safety Valve.*—The position of the safety valve over the throttle valve, though it does not affect the working of the engine, materially lessens the liability to accident, by indicating more clearly the pressure of the steam, from the circumstance of its being received from too close a proximity to the surface of water in the boiler.

159. *General arrangement.*—By this system of arrangement, greater care can be bestowed on the strength and dimensions of the working parts ; and in case of accident, as every part is in sight, it can immediately be attended to. The increased economy of our engines over those of English manufacture is obvious, when the expense of repairs is taken into consideration—many of the engines working for months without requiring the expenditure of a single dollar.

160. These engines are as well calculated for speed as the others, although the roads upon which they run are perhaps not so perfect in their construction ; and it is a source of pride to us to feel, that we have equalled, if not surpassed our master in his own peculiar province.

161. *The Slide.*—One of the most important subjects for consideration, in estimating the value of a locomotive engine, as regards its tendency to increase or diminish speed, is the slide, upon the lead of which much depends. In engines such as were at first imported from England, the lead was invariably on the steam side, varying from one to five-eighths ; and this plan has been in use here until very lately. The advantage gained by the different degrees of lead with certain loads is subjoined in a tabular form, to enable the engineer to decide at once upon what lead will suit his work best.

Practical Table of Gain in Speed by various degrees of Lead of the Slide.

Particulars of Engine.	Gr. load in tons.	Velocity in miles per hour, the lead of the valve being			
		0	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{5}{8}$
	tons.	miles.	miles.	miles.	miles.
Diam. of cylind., 11 inches,	50	31.02	31.52	32.51	34.23
Stroke, 16 inches,	100	21.68	22.02	22.72	23.92
Wheels, 5 feet,	141	17.39	17.66	18.22	19.18
Effective pressure, 50 lbs.,	155	16.28	16.54	17.06	0.
per square inch.	163	15.72	15.96	0.	0.
	165	15.58	0.	0.	0.
	50	27.80	28.24	29.13	30.68
Diam. of cylind., 12 inches,	100	20.05	20.37	21.01	22.12
Stroke, 16 inches,	150	15.68	15.93	16.43	17.30
Wheels, 5 feet,	168	14.56	14.79	15.25	16.06
Effective pressure, 50 lbs.	183	13.72	13.94	14.38	0.
per square inch.	193	13.22	13.43	0.	0.
	196	13.11	0.	0.	0.
	50	26.16	26.57	27.41	28.86
Diam. of cylind., 12 inches,	100	19.85	20.16	20.80	21.90
Stroke, 18 inches,	150	15.99	16.24	16.75	17.64
Wheels, 5 feet,	188	13.93	14.15	14.60	15.37
Effective pressure, 50 lbs.	207	13.09	13.30	13.72	0.
per square inch.	217	12.69	12.89	0.	0.
	221	12.53	0.	0.	0.

The above table is extracted from Pambour's "Experiments on Locomotive Engines."

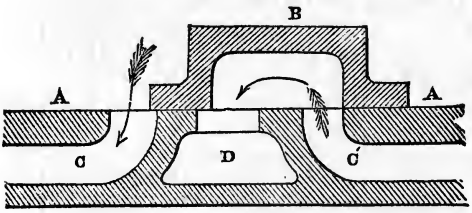
Thus, then, it is evident that too great a lead detracts from the power of the engine; care must therefore be taken not to exceed certain limits.

The lap or cover of the valve, is another matter to be considered; it is a certain excess of face on the steam side more than the steam opening for the purpose of cutting off the steam at any desired portion of the stroke.

The practice, as stated above, was followed nearly by all engineers until very lately, when it was discovered, that by

giving a lead to the exhaust, a very increased effect was obtained; upon trying the experiment again, the result was equally satisfactory, in consequence of which the old slide has been removed and a new one substituted in several instances. The following diagrams will more fully show the extent of lead and manner of adjustment.

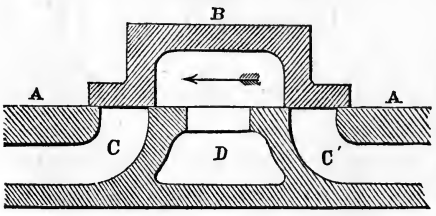
DIAG. A



A A, the face of the valve.
B, the slide.
C C′, the steam-ways.
D, the exhaust opening.

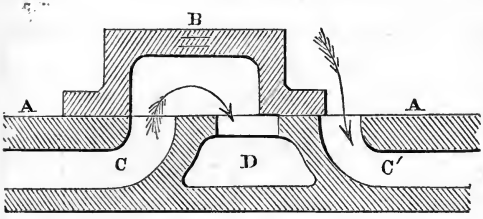
In this diagram, the piston is at the top stroke, and consequently the steam is passing out in the direction of the arrow through C′ and D; the lap of the valve over C shows the amount of cut-off of the slide; the projection of the inside of the face of the slide is not found to be at all objectionable, which is decidedly a fortunate circumstance, as the requisite lead cannot be obtained without it.

DIAG. B.



shows the slide at the half stroke; the two steam-ways are shut, and the exhaust alone open; here then arises the benefit: upon the slide moving in the direction of the arrow, the exhaust is opening, and the elastic force of the confined steam instantly causes it to escape, in a great measure, before the new steam, of a greater elasticity, enters the other end of the cylinder, and thus prevents that forcing which otherwise takes place, from the circumstance of the fresh supply having a greater velocity than that already used.

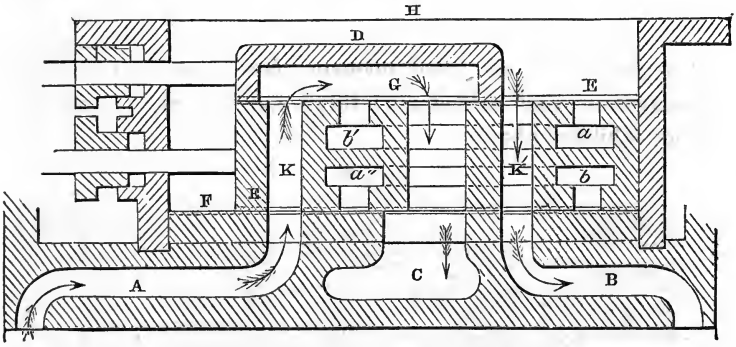
DIAG. C.



In this diagram, the piston is at the bottom stroke; the arrows denote the direction of the steam and exhaust currents. The letters refer to the same parts in each diagram.

Facility in reversing the motion has long been a very great desideratum, and many very ingenious arrangements have been executed, all of which answer the purpose with greater or less effect; but none of them seem to have given complete satisfaction. The annexed diagrams will explain a method used and invented by that ingenious mechanic, Mr. Harrison, of Philadelphia.

DIAG. D

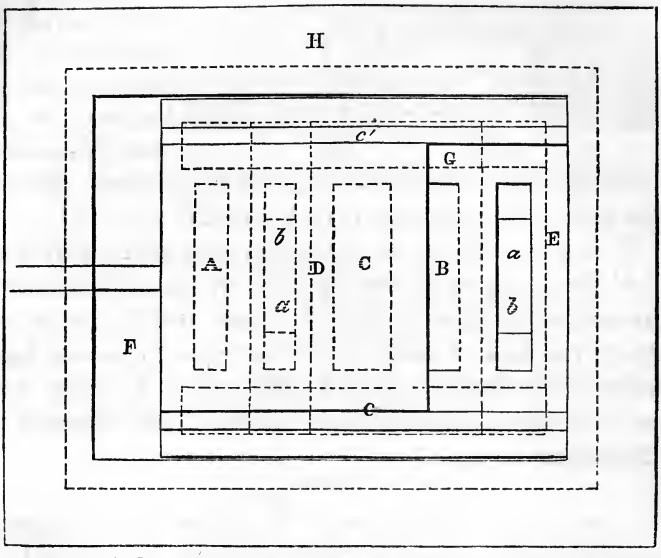


represents a section of the valve-box, slide, and reversing face; A and B the steam-ways; C, the exhaust passage; D, the slide; E E, the reversing face; F, the face of the valve; G, the face of the reversing face; H, the valve-box; K K, ordinary steam openings.

In this position, the engine is going forward; the steam entering the cylinder at B, and exhausting from A; the slide D being a simple slide made according to the old rule.

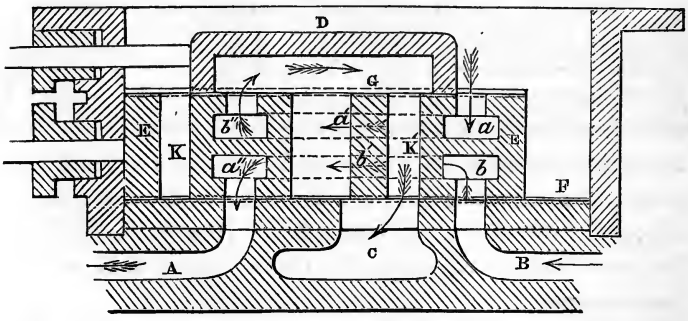
In this case, therefore, or when the engine is advancing, the action is merely that of a common slide.

DIAG. E



is a plan of the slide and reversing face, showing the steam passages on each side at *c' c;* this is the plan of the arrangement exhibited above.

DIAG. F.



Here the face is reversed; that is, the ordinary steam opening K′ in the reversing face, by moving the reversing face, is brought over the exhaust C, and the other opening K is closed by being brought over the valve face; the slide D remaining in the same position, the action is as follows:—The steam

passes from the boiler through a, along the passage a', through the opening a'', into the steam-way A, whence it acts upon the piston; in like manner the exhaust steam passes from the steam-way B into the opening b, along the passage b', into the opening b'', whence it escapes into the exhaust C. Thus the operation of reversing is performed instantly, and without any trouble; the only danger is in the engineer reversing too suddenly under high speed.

162. *Locomotive Engines.* Although the usual rule for calculating the power of the steam engine (page 161,) is sufficiently well adapted to fixed and marine engines, it will be seen that it is altogether inapplicable to locomotive engines—and for the following reasons:—

1st. According to the generative power of the engine.

2d. According to the ratio of speed between the piston and periphery of the driving wheel.

3d. The speed or velocity of the piston varies according to the load to be conveyed.

4th. According to the pressure on the piston; and

5th. According to the plane of the road.

163. In land or fixed engines, we have a certain speed, to secure which we apply the governor, and the slightest variation is corrected; thus adapting the supply of steam to suit the load. We also apply the vacuum gauge, and ascertain exactly what the pressure on the piston actually is; consequently, the rule holds good.

164. In marine engines we estimate the power, knowing the speed of the boat through the water, and its actual resistance at such speed.

165. (1st.) In the locomotive engine we have no constant numbers but the friction per ton, and that varies very considerably—differing, more or less, through every foot of rail passed over, and for each variety of carriage—hence, to settle the power of the engine, we must ascertain the areas of surfaces exposed to the radiation and in contact with the flame, together with the area of fire grate, and quantity of fuel in

fire box. To enable the reader, at a glance, to see the surfaces exposed in different engines, we subjoin the following table; for the sake of comparison, we also insert two of the best English Locomotives, as detailed by Count Pambour, in his "Treatise on Locomotion."

166. *For Table, &c., see the end of the work.*

167. The facts deduced from the table are therefore as follows—viz. That it requires an area of about 38 square feet to be exposed to the radiating action of heat, 375 square feet to contact, 7.33 feet of fire-grate, and 22.33 cubic feet of fuel, to enable a locomotive engine of the usual construction to perform well.

168. (2d,) The length of stroke, and the diameter of the driving wheel are given; the ratio will be the proportion that twice the length of stroke bears to the circumference of the wheel.

169. (3d,) The velocity of the piston varies according to the load to be conveyed. The weight of the engine and the effective pressure being the same, the velocity of the piston will be affected by any addition or diminution of load; for an engine will not draw 200 tons at the rate of 25 miles per hour, if its utmost power is 150.

168. (4th,) Again, the velocity of the piston varies with the effective pressure; if 50 lbs. per square inch enables an engine to draw 150 tons at 25 miles per hour, the friction, or adhesion of the driving wheels to the rails remaining exactly the same, 40 lbs. will not be sufficient to do the same, as it will not exert a power on the piston great enough to overcome the resistance of the train.

169. (5th,) The piston is again subject to another obstacle, which materially affects its speed, namely, the plane of the road—for, in ascending a plane, however trifling the grade, an increase of power is absolutely indispensable;—thus the engine which can draw 150 tons at 25 miles on a level, can only draw, say 75, upon an inclined plane; the balance of the 150 being absorbed in overcoming the extra resistance of the engine itself,

as well as of the whole train. Having premised thus much, on reference to the table (which will be found at the end of this volume), the working parts of the different engines will be seen at a glance.

171. Upon consideration it will be seen, that although 50 lbs. may be the effective pressure of the steam, it does not follow, as a matter of course, that by taking away a considerable part of the load, a proportionate increase of speed will be attained, —for this depends not upon the pressure, but upon the generative power of the boiler; for instance, the engine that can convey 150 tons on a level, at the rate of 25 miles an hour, may not be enabled to move even itself at the rate of 50, for although its generative power be equal to 1864 cylinders of steam per hour, yet it has not power to double that supply, or to increase it at all at the same rate, that is, in the same time—hence it becomes necessary to keep these facts in mind during the following calculations.

172. From experiments by Pambour, it appears, that the power requisite to draw one ton weight on a level amounted to 8 lbs.

173. *Practical Rules for calculating the power of Locomotive Engines.* Before entering into any calculations, we here subjoin the value of the signs made use of, in the following formulæ.

174. m = The gross load in tons.
M = The gross load in pounds.
n = The resistance per ton, or 8 lbs. per ton.
c = The rise of unity in proportion to the length of the plane.
R = The resistance of the periphery of the driving wheel.
D = The diameter of the driving wheel in inches.
a = The diameter of the cylinder in inches.
l = The length of the stroke in inches.
f = The friction of the engine.
p = The atmospheric pressure.
P = The pressure per square inch on the piston.

H = The horse power.

C = The constant number, which is explained in Rule VI.

V = The velocity of the engine.

175. *Rule* 1. To find the resistance to traction on the periphery of the driving wheel.

Multiply the gross load, expressed in tons, by 8, and the product will be the resistance on a dead level.

Example. The engine 'Uncle Sam,' weighs

	10.5	Tons.
Tender, .	7.0	"
Train, . .	100.0	"
	117.5	
	8	
	940.0	Traction on a dead level;

or, by formula, $m\ n$, or $8\ m$.

176. *Rule* 2. To find the effective force of gravity, when the engine and train are running on an inclined plane.

Divide the gross load in lbs. by the length of the plane corresponding to an ascent or descent of unity, the quotient will be the force in lbs. acting down the plane.

Example. The engine, tender, and train, weigh, as above, 117.5 tons, which, multiplied by 2240, equals 263,200 lbs.

The plane equals a rise of 1 in 128, and

128)263,200.00(2056.25 lbs. the effect of gravity.
256
720
640
800
768
320
256
640

or, by formula, $\frac{M}{c}$ = effect of gravity.

For ascending an inclined plane, the effect of gravity, as above, must be added to the traction on a level; and descending, must be subtracted.

Thus, if the engine and train be ascending an incline of 1 in 128, we have per last rule,

Effect of gravity, 2056.25 lbs.
Traction on level, 940.

Which give 2996.25 lbs. traction up the plane; or, by formula for ascending, $m\ n + \frac{M}{c}$

or $8\ m + \frac{M}{c}$

for descending, $\frac{M}{c} - m\ n$

or $\frac{M}{c} - 8\ m$

177. *Rule* 3. To find the whole force or resistance to be overcome by the engine.

Determine the resistance to traction, by Rule 1; add to it one-eighth part, for the additional friction it causes on the engine, and 6 lbs. per ton of the weight of the engine for its own friction; the sum will express the whole force or resistance to be overcome by the engine.

Thus by formula, $9\ m + f = R$.

178. *Rule* 4. To find the effective pressure on the piston in lbs. per square inch.

Multiply the resistance at the circumference of the wheel by its diameter in inches, and then divide by the product of the square of the diameter of the cylinder into the stroke. The quotient will express the pressure in lbs. per square inch on the piston, and adding 14.7 lbs. for the pressure of the atmosphere, the result will be the effective pressure in lbs. per square inch on the piston.

Example. The weight of the engine is 10.5 tons, the tender,

7 tons, the train, 50 tons; the diameter of the driving wheels, 54 inches; the diameter of the cylinders, 11 inches; and the length of stroke, 18 inches. It is required to find the pressure of steam in the cylinder to sustain an uniform velocity up an incline of 1 in 140.

Engine weighs . . . . 10.5 tons.
Tender " . . . . 7.0 "
Train " . . . . 50.0 "

Gross load, " . . . . 67.5 "
8

Hor. tract., " . . . . 540.0 lbs.

Gross load, 67.5
2240

27000
1350
1350

140)151200.0(1080.lbs. effect of gravity.
140

1120
1120

Effect of gravity, 1080
Horizontal traction, 540

Inclined traction, 1620 lbs.
Additional friction, 202.5 $= \frac{1620}{8}$
Friction of engine, 63. at 6 lbs. per ton.

Resistance, 1885.5
Diameter of wheel, 54.

75420
94275

101817.0

Diameter of cylinder, 11.² inches, × length of stroke, 18.

$$11.^2 \times 18 = 2178$$

2178)101817.0(46.74 lbs. pressure on piston.

8712

14697

13068

16290

15246

10440

46.74

14.7

61.44 lbs. effective pressure of steam required;

or, by formula, thus, $\frac{\left(\frac{9\,M}{8\,c} + 9\,m + f\right)D}{d^2\,l} + p = P.$

179. *Rule* 5. To determine the power of a locomotive engine.

Find the resistance by Rule 4, and then the power by rule, as follows: multiply the resistance by 8 times the velocity in miles per hour, and divide by 3.000, the result will express the horses' power.

Example. Take the last case, and suppose the velocity to be 12 miles per hour.

The resistance is, . . . 1885.5 lbs.

12 × 8 = speed, . . 96.

113130

169695

3.000)181008.0

60.336 horse power.

Or, by formula, $\frac{R \times 8V}{3.000} = H.$

20

The power of a locomotive engine being known, it is required to determine the speed under any given circumstances of load, inclination of railway, &c.

180. *Rule* 6. Find the whole resistance to be overcome; multiply the number of horses' power by 375, and the product will be a constant number, to be divided by the resistance, to obtain the velocity in miles per hour.

Example 1. Taking the foregoing case.

Horse power, = 60.33
375

30165
42231
18099

Constant number, 22623.75

The resistance is 1885.5, then

1885.5)22623.75(11.99 miles per hour.
1885.5

37687
18855

188325
169695

186300
169695

or, by formula, $375\ H = C$ and $\frac{C}{R} = V$.

For the velocity when the railway is horizontal, we have

Horizontal traction,	540 lbs.
Additional friction,	67.5
Friction of engine,	63.
Resistance, . .	670.5 lbs.

and 670.5)22623.75(33.74 miles per hour.

20115

25087
20115

49725
46935

27900
26820

1080

The force arising from gravity being greater than the horizontal traction, in this example, the carriages would, of themselves, run down the inclined plane, with an accelerated velocity; and this would occur in all cases, where the inclination is greater than 1 in 280.

Example 2. To find the greatest uniform velocity of the same engine and train, down an inclination of 1 in 600.

Horizontal traction, 540 lbs.

$\frac{67.5 \times 2240 \text{ lbs.}}{600} = 252$ effect of gravity.

Inclined traction down the plane, 288 lbs.
Additional friction, ... 36
Friction of engine, ... 63

Resistance, ... 387 lbs.

and 387)22623.75(58.45 miles per hour.

1935

3273
3096

1777
1548

2295
1935

The velocity by rule would therefore be about 58 miles per hour; but this is more than would occur in practice, owing to the imperfect state of the road and the resistance offered by the atmosphere, which from experiments long since made, we know exerts a pressure of .915 lbs. per square foot of surface at the rate of 20 miles an hour.

181. For any particular engine, the constant number, which forms the dividend, when once found, will be ready for any particular application.

In the calculation of the average speed, the distances traversed, or the time of transit, care should be taken not to overlook the circumstance, that nearly one half of the distances passed over in the gradual production and annihilation of velocities may be considered lost.

182. By means of the foregoing rules, the mechanic will readily be enabled to calculate what any engine is doing, or what any proposed engine can do; the velocities of transit, pressure of steam, and weight of train being fixed upon; or inversely, having a certain weight to be moved, he can ascertain the power and weight necessary to convey the same.

183. For those however, who are familiar with the application of Algebraic formulæ, we here subjoin a synoptical table from the foregoing rules.

1. The power of a locomotive engine being known, it is required to determine the speed under any given circumstances, of load, inclination of railway, &c.

$$\frac{C}{\left(\frac{9\,M}{8\,c}+9\,m+f\right)}=V \text{ the speed or velocity.}$$

2. To find the resistance or load, the velocity and power being given.

$$R=\frac{C}{V}.$$

3. To find the pressure of steam required in the cylinder, the load and inclination of road being given.

$$\frac{\left(\frac{9\,M}{8\,c}+9\,m+f\right)D}{d^2\,l}+p=P \text{ pressure per inch.}$$

4. The maximum load an engine is able to draw at a determined pressure.

$$\frac{(P-p)\,d^2\,l}{D}=\text{the maximum load.}$$

5. The pressure, load, and diameter of driving wheel given, to find diameter of the cylinder.

$$d=\sqrt{\frac{\left(\frac{9\,M}{8\,c}+9\,m+f\right)D}{(P-p)\,l}}$$

6. To find the power of the engine.

$$\frac{\left(\frac{9\,M}{8\,c}+9\,m+f\right)8\,V}{3.000}=H \text{ the horse power.}$$

7. To find a constant number to be divided by the resistance, which shall give the velocity with the maximum load.

$$C=H\times 375.$$

PART V.

PRACTICAL RULES.

RULES

FOR CALCULATING THE POWER AND WORKING PARTS OF A STEAM ENGINE.

184. To find the power of steam engine. The standard being 33000 lbs. raised one foot high per minute, or 150 lbs. raised 220 feet in the same time, which effect is equal to one horse power.

Multiply the pressure per square inch by the area of the piston, that product by the velocity in feet per minute, and divide by 33000 lbs., the quotient is the number of horses' power.

185. There are, however, two other circumstances to be taken into consideration; namely, the friction of the engine, and the expansion of the steam.

The friction in a high pressure non-condensing engine, will, with the atmospheric pressure, average 18 lbs. per square inch on the piston. In condensing engines, however, the case is different; with an average vacuum of 27 inches, the atmospheric pressure being 14.7, or = 30 inches of mercury, we have 30 : 14.7 : : 27 : 13.23; and 15 — 13.23 = 1.77, to which must be added for the friction and inertia of the engine 8 lbs.: thus making a total of 9.77 lbs. per square inch on the piston.

The next consideration is the expansion of the steam when cut off at any portion of the stroke, and the rule for finding the mean effective pressure is as follows:

186. Divide the length of the stroke in inches by the distance in inches the piston has moved beforethe steam is cut off, and divide the whole pressure on a square inch of the piston in lbs. by the quotient. Add 1 to the hyperbolic logarithm of the

number of times the steam is expanded, and multiply the logarithm by the number of lbs. to which the steam is expanded, and the product is the uniform force of the steam.

TABLE XV.—*Hyperbolic Logarithms.*

No.	Log.	No.	Log.	No.	Log.	No.	Log.
1¼	.2231435	5¾	1.7491998	15	2.7080502	33	3.4965075
1½	.4054651	6	1.7917594	16	2.7725887	34	3.5263605
1¾	.5596157	6¼	1.8325814	17	2.8332133	35	3.5553480
2	.6931472	6½	1.8718021	18	2.8903717	36	3.5835189
2¼	.8109302	6¾	1.9095425	19	2.9444389	37	3.6109179
2½	.9162907	7	1.9459101	20	2.9957322	38	3.6375861
2¾	1.0116008	7¼	1.9810014	21	3.0445224	39	3.6635616
3	1.0986123	7½	2.0149030	22	3.0910424	40	3.6888794
3¼	1.1186549	7¾	2.0476928	23	3.1354942	41	3.7135720
3½	1.2527629	8	2.0794415	24	3.178053	42	3.7376996
3¾	1.3217558	8½	2.1400661	25	3.2188758	43	3.7612001
4	1.3862943	9	2.1972245	26	3.2580965	44	3.7841896
4¼	1.4469189	9½	2.2512917	27	3.295836	45	3.8066624
4½	1.5040774	10	2.3025851	28	3.3322045	46	3.8286414
4¾	1.5581446	11	2.3978952	29	3.367295	47	3.8501476
5	1.6094379	12	2.4849066	30	3.4011973	48	3.8712010
5¼	1.6582280	13	2.5649493	31	3.4339872	49	3.8918203
5½	1.7047481	14	2.6390573	32	3.4657359	50	3.9120230

To convert common logarithms into hyperbolic, multiply the former by 2.3026.

188. Before proceeding with the calculations, we subjoin the value of the several signs made use of.

d	represents	the diameter of the cylinder.
a	"	the area of the cylinder.
l	"	the length of the stroke in inches.
l'	"	the length of cut-off in inches.
P	"	the pressure in the boiler.
p	"	the atmospheric pressure.
x	"	the uniform pressure.
f	"	the friction of the engine.
V	"	the velocity in feet per minute.
33000		the standard of horse power.
H	"	the horse power of the engine.

To find the area of the cylinder, square the diameter and multiply by .7854.

Thus $d^2 \times 7854 = a$.

To ascertain the friction of the engine, multiply the area of the piston by 9.77.

Thus $a \times 9.77 = f$.

Example. Required the power of an engine, of which the dimensions are as follows :

Diameter of cylinder, ... 42 inches.
Length of stroke, ... 11 feet.
Cut-off at . . . . . $\frac{1}{4}$ of the stroke.
Pressure on the boiler, ... 50 lbs. per sq. inch.
Strokes per minute, ... 44.

1st, To find the mean effective pressure.

$11 \times 12 = 132$ inches $132 \div 4 = 33$ inches, length of cut off $132 \div 33 = 4$, the number of times to which the steam is expanded; then, per table, the hyperbolic logarithm of 4 is 1.386, and $1.386 + 1 = 2.386$, and $50 \div 4 = 12.5$. Hence

2.386
12.5

11930
28632

29.8250 the mean effective pressure in lbs. per square inch on the piston.

2d, To find the area of piston and thence the power.

$42.^2 \times .7854 = 1385.44$ area; $1385.44 \times 29.82 = 41{,}313.92$ the pressure on piston; $41{,}313.92 \times 484 = 19{,}995{,}927.6$ lbs. lifted one foot high per minute, which divided by 33000, gives the number of horses' power.

33000)19995927.6 (605.93 horse power.
198000

195927
165000

309276
297000

122760

605.93 will therefore be the actual power of the engine; but as a portion of that power is absorbed in moving the parts, that amount must be deducted to obtain the available or effective power of the engine. Thus

1385.44 = the area,
9.77 = the friction per square inch.

969808
969808
1246896

13535.7488 friction of the engine.
41313.92
13535.14

27778.78
484 velocity in feet per minute.

11111512
22222544
11111272

33000)13444639.12 (407.41 effective horse power.
132000

244639
231000

136391
132000

43912

Or, by formula.

$$1st,\ x = \frac{P}{l \div l'} \times \left(\text{hyp. log.}\ \frac{l}{l'} + 1\right)$$

$$Or,\ x = \frac{P}{l \div l'} \times \left(2.3026 \log.\ \frac{l}{l'} + 1\right).$$

$$2nd,\ d^2 \times .7854 = a$$

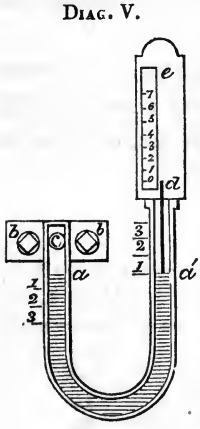
$$\frac{V.\ a.\ x}{33000} - f = \text{the effective horse power.}$$

$$Or,\ \frac{V.\ a.\ x}{33000} = H.$$

189. When the pressure in the boiler does not exceed the load or weight on the safety valve, the following method has been long used for ascertaining what the pressure actually is.

A tube of iron A is bent, as represented in the diagram, and filled with mercury to the level $a\ a'$, making a length of 14 inches of mercury; it is then attached to some accessible part

DIAG. V.



of the boiler by means of bolts at $b\ b$; the hole c allowing a free communication between the level of the mercury at a, and by means of the mercury with the atmosphere also; d is a small stick of pine wood (that being the best material for the purpose), which floats on the mercury at a', and as the mercury rises or falls from the pressure of the steam, so the upper end of the stick travels on the face of the index, and by its position points out the pressure on the boiler. Thus when the mercury at a is forced down one inch, the mercury in the other leg at a' rises one inch also, which together make two inches, and as two inches of mercury nearly equal 1 lb. pressure on the square inch, the steam is sustaining a column of mercury equal to two inches, or the pressure on the boiler is 1 lb. per square inch.

This apparatus is not so convenient where steam of very high temperature is used, on account of the necessary length required ; it is, nevertheless, generally used on the boats navigating our waters.

190. *Safety Valve.*—From the intimate connection which exists between the generating surface and the dimensions of the safety valve, it becomes necessary that the former should enter into the calculations for the dimensions of the latter; and for this reason : a safety valve to be efficient should be of such dimensions as to allow the escape of steam to equal or rather exceed the generation; otherwise steam would increase in the boiler and cause explosion. Such being the case, we will proceed to inquire into the proportion requisite to be kept between the two. It has been found by experiment, that it requires about 1.5 foot area of generating surface to convert a cubic foot of water into steam ; but for security, we will take only two-thirds of that quantity, and suppose that for every square foot of surface a cubic foot of water is evaporated, then the rule will be as follows :

191. Divide the area of fire surface by the number corresponding to the pressure or temperature in the annexed table, and the quotient will be the square of the diameter of the valve in inches.

TABLE XVI.

Pressure in inches.	Temperature.	Density.	Divisor.
30	212°	1.00	0
35	225	1.28	5
60	250	2.00	15
90	275	2.85	29
120	293	3.70	45
150	308	4.70	60

Example. Required the area of a safety valve for a low pressure boiler, with 80 feet fire surface ; 5 is the divisor, as per table.

Then $\frac{80}{5} = 16$ the square of the diameter,

and $\sqrt{16} = 4$, which is the diameter.

Or, by the following rule :

Divide the area of the fire surface by the excess of pressure above the atmosphere in lbs. per square inch, and the quotient will be the square of the diameter.

Example. Thus $\frac{80}{5} = 16$, and $\sqrt{16} = 4$ the same as above.

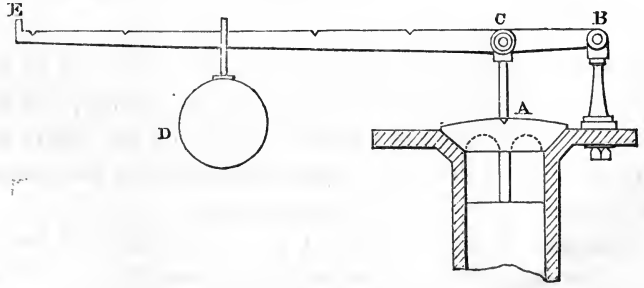
Having thus found the diameter of safety valve, we proceed to ascertain the weight to be placed upon it, and the length of lever.

Rule. Find the area of the valve, and multiply by the pressure in lbs., the result will be the required weight.

Example. The diameter is 4, and $4^2 \times .7854 = 12.566$ area $12.566 \times 5 = 62.830$ lbs. on the valve.

The annexed diagram represents the usual form of arranging the weight, lever, and valve. A is the valve, the area of which we suppose to be 12.566 ; B is the fulcrum of the lever E B ; and C is the point where the pressure is acting on the lever ; required the weight of the ball D to counteract or balance the pressure on the valve, supposing the leverage to be three to one.

DIAG. VI.



192. Divide the pressure by the distance, and the quotient, minus the weight of the valve and lever, will be the weight required.

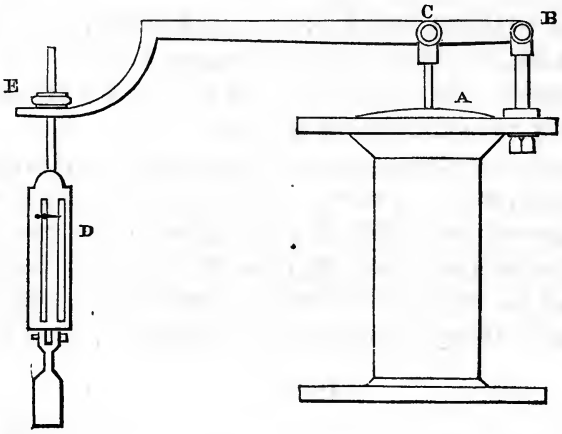
Example. Thus, $\frac{62.83}{3} = 20.943$ lbs.

The weight of valve = 3. lbs.
Do. of lever = 4.5
7.5

and, 20.94 — 7.5 = 13.44 lbs. weight of ball.

193. For locomotive engines, and where the boiler is in constant motion, the spring balance has been attached to the lever, and by means of the thumb screw E, the spring can be adjusted

DIAG. VII.



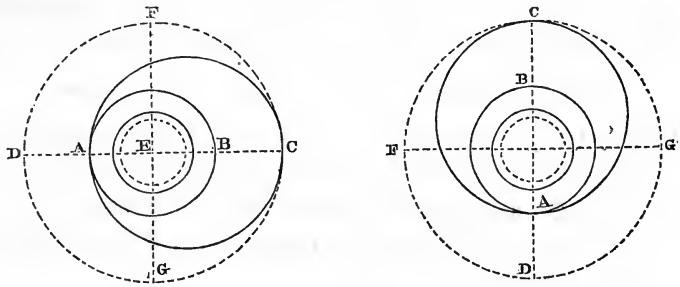
to any number of lbs. on the face of the index. The rule for calculating the pressure on the valve A is, to multiply the difference in leverage by the number of lbs. on the index, and with the area of the valve divide the above sum; the quotient will be the pressure in lbs. per square inch.

Example. The leverage is 4 to 1, the number of lbs. on the index 40, and area of valve 12.56; then $40 \times 4 = 160 \div 12.56 = 12.73$ lbs. per inch. The exact angle for the seat of the valve has never yet been accurately determined; it is usual, however, to make the angle less than 45°, and in many cases

the seat of the valve has been made perfectly horizontal, which, where circumstances will permit, is probably the best.

194. *The Eccentric.*—The motion of the slide, or the distance that the valve has to travel, together with the length of lever, most convenient for the particular circumstances of the case, will determine the throw of the eccentric. The throw of the eccentric is the distance between B C and the distance travelled by the point C.

DIAG. VIII.



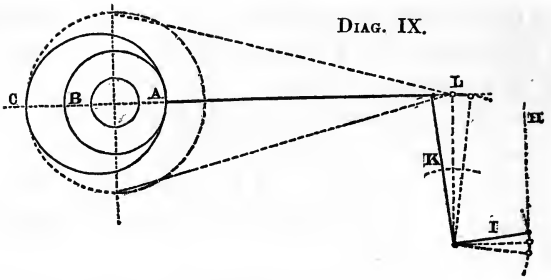
is shown by the dotted circle C D. The crank shaft is represented in section at E, and the eccentric being fixed upon it, the point C will, at the different positions of the eccentric be, consecutively in its journey round, at the points F D G.

195. *Example.* The motion of the valve at H is $2\frac{1}{2}$ inches, and the lever I is $9\frac{1}{2}$ inches; what is the requisite throw for the eccentric, K being twice the length of I? K will, therefore, equal 19 inches, and consequently its extremity L will move through twice the space travelled by I, or will equal 5 inches; which will be the required throw of the eccentric.

Or, as follows, $9\frac{1}{2} : 19 :: 2\frac{1}{2} : 5$.

The dimensions of the collar B A must be made to suit the diameter of the crank shaft, due care being taken to give sufficient quantity of metal to the collar to prevent the possibility of fracture; the throw of the eccentric must then be set off on the centre line from B to C, and the centre found by rule in art. 238.

Diag. IX.



Again, the motion of the slide is to be 5 inches, but the throw of the eccentric only $2\frac{1}{2}$; what must be the proportion of the levers K and I to make the arrangement complete?

$2\frac{1}{2} = \frac{5}{2}$; therefore, if K be made = 16 inches,

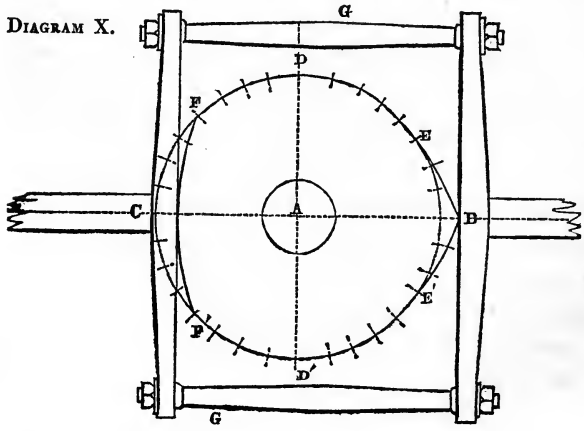
I will = $16 \times 2 = 32$ inches; or, if I = 16, K must = 8 inches,

The general rule will therefore be, multiply the stroke of the valve by the eccentric lever, and divide the product by the length of the valve lever; the quotient will be the required throw of the eccentric. Thus,

$$H \times K \div I = \text{the throw of the eccentric.}$$

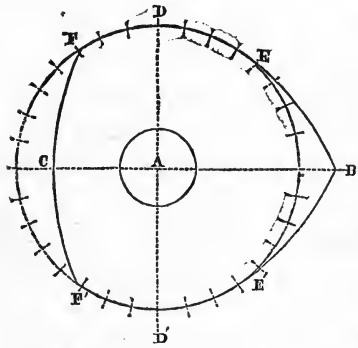
196. *Cambs.*—For the purpose of using steam expansively, a very ingenious and simple method has obtained for setting off the cambs, so as to cut off at any required part of the stroke. The annexed diagram will illustrate the method of laying off a camb to cut off at one-half the stroke.

Diagram X.



The circle B D C is described, and its circumference divided into 32 equal parts; four of which are set off from D D′ to E and E′, and four set off to F F′; then with the points F F′ as centres and distance D D′, the diameter of circle as radius, describe the arcs E B and E′ B, cutting one another in B; and with the centre B and the same radius describe the arc F C F′; then if the frame G G be made to touch the camb at C and B, it will form a half-stroke camb—for B C equalling D D′, and the arcs F E and F′ E′ together equalling half the circumference of the circle, the slide G G will remain stationary during half the time of the revolution of the shaft; that is, one quarter of the revolution at the top, and one quarter at the bottom.

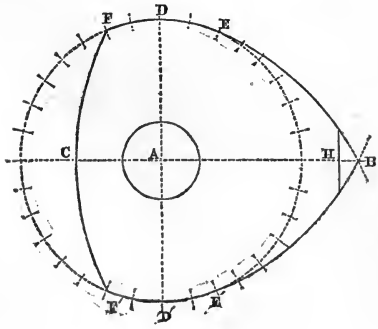
DIAG. XI.



197. To produce a camb that shall cut off five-eighths of the stroke, divide the circle as before, and set off $\frac{3}{3\,2}$ or three divisions on each side of D D′; then with the radius D D′ and centres F F′ describe the arcs E′ B and E B, cutting each other in B; and with centre B and same radius describe the arc F C F′; then will this camb cut off $\frac{5}{8}$ of the stroke.

198. In the same manner again, for a $\frac{3}{4}$ camb: divide as before, setting off only two divisions on each side of D D′, and with the same radius describe arcs cutting each other at B; and with B as centre and the same radius describe the arc F C F′. But as the motion which would be produced by the line A B is greater than is required, a portion H B is cut off,

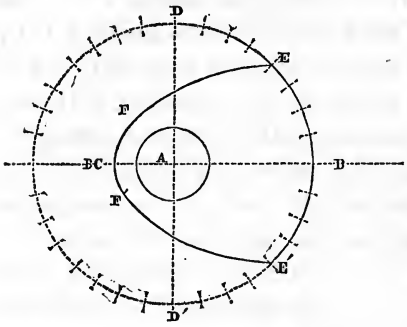
DIAG. XII.



equal to the amount of its excess; then will this camb cut off three-quarters of the stroke.

199. Finally, for what is termed the whole-stroke camb, the circle is divided as before, four divisions being set off from D D' to E E'; then, with the distance E E' as radius and E' E as centre, describe the arcs E F and E' F', and with the same distance as an ordinate, find the curve F C F'; then will this be a whole-stroke camb.

Diag. XIII.

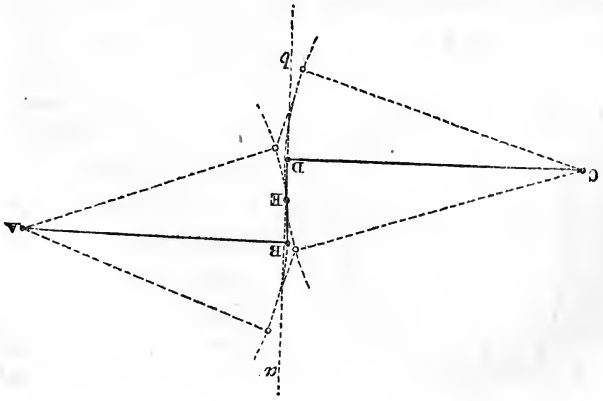


These cambs are entirely used on the Western waters, and the expense of the separate cut-off valve thus obviated.

200. The above method may be carried out to any degree of cut-off required, by dividing the circle into any other number of equal parts, as into tenths or twelfths. From the circumstance of their having originated at Pittsburgh, they still bear the name of Pittsburgh cambs. The name, however, of the very ingenious projector has been unfortunately lost.

201. *Parallel Motion.*—The arrangement generally used for

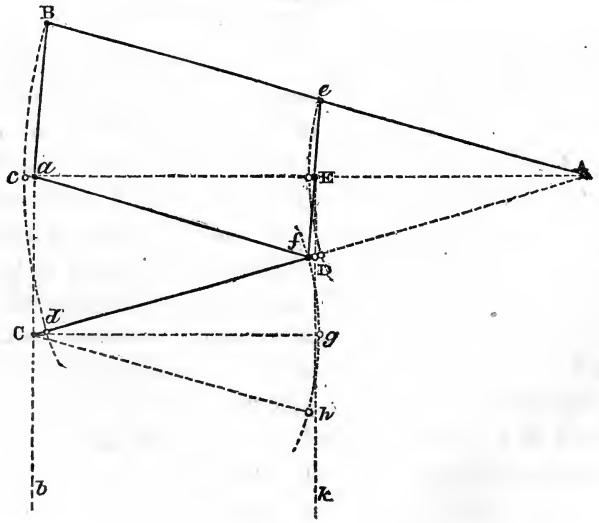
Diag. XIV.



land engines, is Bolton and Watt's original invention; and is thus arranged: Suppose A (diag. 14) to be the centre of a beam, of which B A represents one half; and suppose C to be the centre of a radius rod, or another beam of equal length, and B D a rod or link connected with the beam and radius rod at B and D, the point E, being the centre of link B D, will travel up and down in nearly a vertical line *a b*; and if the piston rod of an engine be attached to E, it will be held in a vertical position during its ascent and descent. The air-pump connecting rod is usually attached to the beam in this manner.

202. The following is the method of finding the length of the radius and parallel rods and links geometrically: With the centre A and distance A B (equalling half the beam) describe the arc B *c d*, whose chord shall equal the length of the stroke; bisect A B in *e*, and with A *e* as radius and centre A, describe the arc *e f*; from A draw a straight line through *f* and *d*. Bisect the versed sine of the arc B *c d*, and let fall a perpendicular line *a b*, cutting A C in C, then with C as centre and radius A *e* describe the arc D *g h*; join the points B *a*,

DIAG. XV.



e D, *a* D and D C; then B *a* (the front link) will equal *e* D (the back link), and *a* D (the parallel rods) will equal C D (the radius rod), and the arc D *g h* will equal the arc *e f*; and as the points *a* D are equidistant from the line A B, and the lines *a* D and D C are equal to each other, the point *a* in its rise and fall will be kept parallel to the point E, and will travel in a direction *a b*, which will be nearly vertical.

203. Or, the following formula may be used to obtain the various lengths:

Let R=the radius of the beam,
l =the length of the parallel bars,
and *r* =the length of radius rods.

204. Then the equation for finding the length of the radius rods, will be as follows:

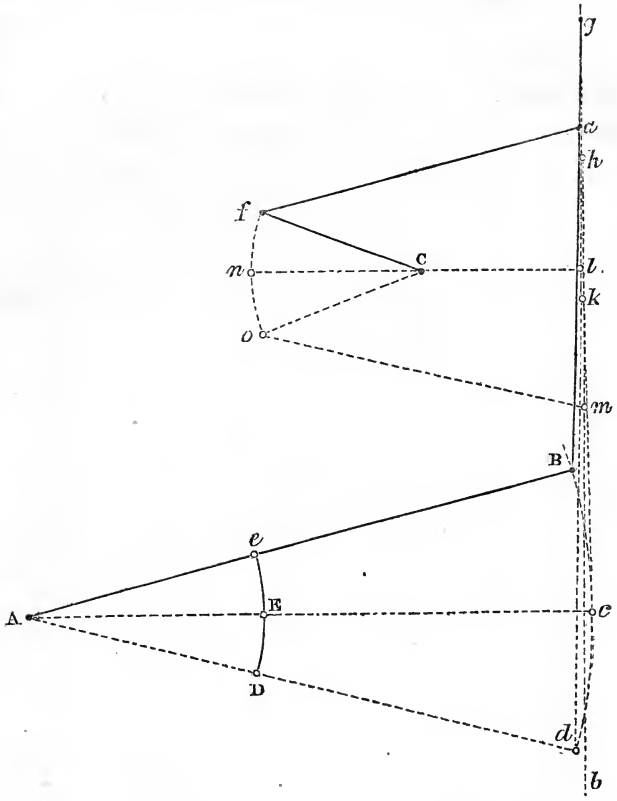
$$\frac{\overline{R-l^2}}{l} = r$$

Example.—Suppose the radius of a beam equals 6 feet 6 inches, or 78 inches, and the length of the parallel bars 34 inches, required the length of the radius rods.

$$78-34=44, \text{ and } \frac{44^2}{34} = 56.35 \text{ inches.}$$

205. The most approved method of arranging the parallel motion for marine engines, is the same in principle, though varied in adjustment. Let A B (diag. 16) represent half the beam; with A B as radius and A centre, describe the arc B *c d*, whose chord shall be equal to the length of the stroke; draw the lines B A, *c* A and *d* A, also from A as centre, and with A D as radius describe the arc D E *e*. Divide the versed sine of the arc described by the end B of the beam, and erect a perpendicular *b g* therefrom; and then from B *c* and *d* as centres, with the length of side rod as radius, cut the vertical line at *g*, *h*, and *k*, the top, middle, and bottom stroke, join the corresponding points *g* B, *h c*, and *k d*; then from *g* set off on the line *g b* the centre of the pin *a* for the parallel rod; in like manner, from the points *h* and *k* set off *l* and *m*; then, from *a l m* as centres and distance B *e*, describe arcs at *f n o*; also from *e* E

DIAG. XVI.



D as centres, describe arcs cutting the former at *f n o*; draw the horizontal line *n l*; with the points *f n o* find the centre of a circle C, the circumference of which shall pass through the said points. Join *f* C, *f a*, and *g* B, and *f* C will be the radius rod, *f a* the parallel rod, and *g b* the link or side rod.

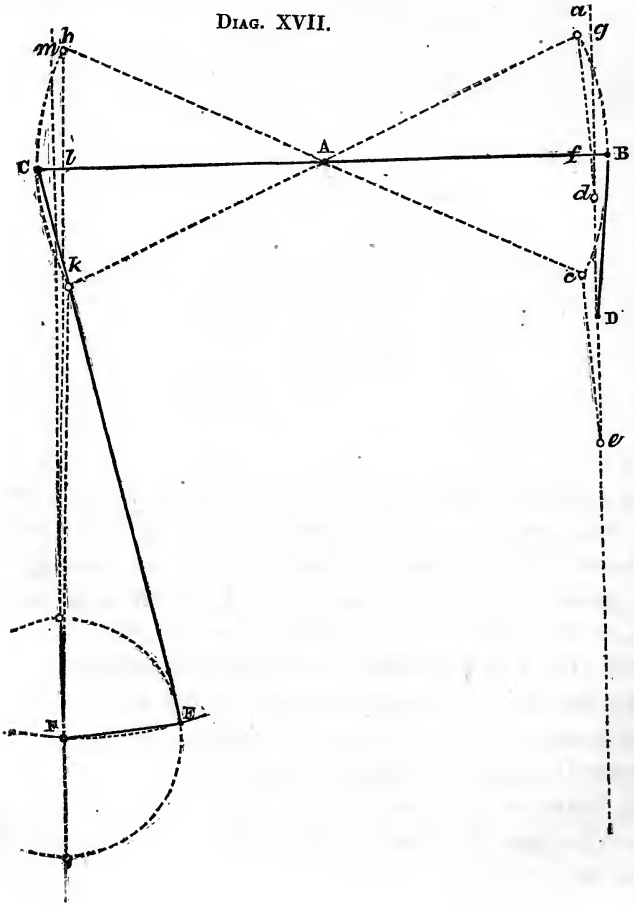
206. The simplest method of producing a perfectly vertical motion for the piston rod, is by means of the slides and connecting rods so much in use in this country. The proportions between the length of stroke and length of connecting rods, or links, having been the result of much and careful investigation and experience, the following table will exhibit the usual dimensions.

Length of stroke, 7 feet.		Length of Links, 4 feet 6 inches.	
" " 9 "		" " 6 " 0	"
" " 11 "		" " 7 " 6	"

The above are the general dimensions of stroke in the boats on the North river. The piston rod cross-head is attached to the end of the beam by means of these links, and its two ends work on slides fixed to the cylinder and framing, so that the motion of the piston rod is truly vertical.

207. The annexed diagram will show the readiest method of finding the centres of an ordinary boat engine. The length of the

DIAG. XVII.

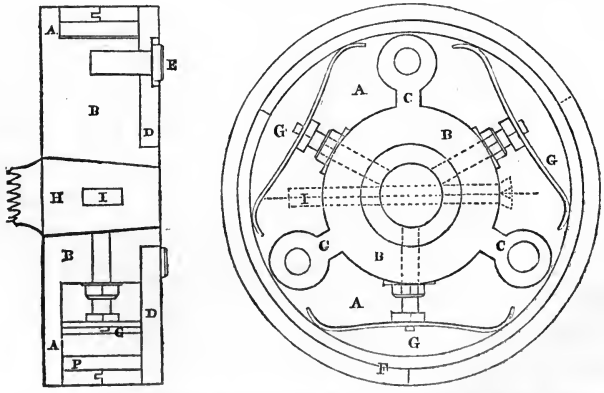


stroke being decided upon, together with the length of beam and position of the paddle shaft as to height, we will proceed to explain and point out the position of the parts.

208. The radius A B being given, and the chord *a c*, find the versed sine *f* B ; bisect the versed sine with the perpendicular *g e*, which will give the centre of the cylinder. In like manner, bisect the versed sine of the chord *h k*, and let fall the perpendicular *m* F, which will give the centre of the paddle-shaft ; then from the points *a*, B and *c* as centres, with the length of the link as radius, cut the vertical line *g e* at *d* D and *e*, which will give the position of the piston rod cross-head at the top, middle and bottom stroke, from which the guides, cylinder lid, &c., must be set off. To find the length of the connecting rod, place the beam horizontally, and from C measure carefully down to F ; then with C F as radius describe the arc F E, cutting the circle described by the crank pin at E, which will be the position of the crank, at half stroke, from which the position of the eccentric and cut-off camb must be decided.

209. *Piston.*—Of the various plans for keeping the piston steam-tight in the cylinder, the arrangement of which the annexed is a diagram appears to be the most perfect. The construction is as follows :

DIAG. XVIII.



The piston consists of a plate A A, having a boss B cast on the centre, with three arms C C C also cast on it, radiating

from the centre, and equidistant from each other; these arms and the centre boss stand up from the plate A, and another plate D of the same thickness as A is put upon them, making the whole thickness of the piston; the plate D is held in its place by a projection on the centre boss passing through it, and is fixed by screws E E countersunk into the plate D and tapped into the arms C C C. The plates A and D are turned so as to be just capable of moving in the cylinder, and three brass or cast iron (which latter material is quite as good as brass, and very considerably more economical) rings F F F are placed between them; the inner ring is equal to the width between the plates, and the two outer ones are each one-half the same; one of the rings having a rebate or tongue projecting on one edge, which is carefully fitted into a corresponding groove on one edge of the other. The rings are turned to fit the cylinder very truly, and after having been hammered all round on the inside, are cut through in one part—the hammering giving them a tendency to expand, thus causing them to fly open when cut. When, therefore, they are put in their places in the cylinder, they press against the cylinder by their elasticity, and keep in such close contact as to make a steam-tight joint during the motion of the piston; the cuts in the rings being placed so as to cross joint.

210. When, however, the rings become much worn, and they have expanded to their utmost, some other means are requisite for keeping them tight against the cylinder; for this purpose, three steel springs G G G are placed in the piston, of the same width as the inner ring, against which they bear; they are retained in their places by means of small pins with collars to them, one end of which is tapped into the centre boss, with a small nut to set it to any required position; the other end pressing against the middle of the spring. When the springs require setting up, by unscrewing the pins a little, and setting up the nut, the springs are made secure. Whilst the rings are new, and until the elasticity is nearly gone, the springs are merely touching the rings; but as the rings wear, so the

springs are put into operation. Access is easily obtained to the springs by taking off the front cover to the cylinder, and by means of the screws E E E, removing the plate D. There are many forms of metallic packings invented by different engineers, many of which are very excellent; but they do not seem to combine simplicity and utility so well as to render them of general use.

211. *Condenser.*—The capacity of the condenser ought to be as large as circumstances would permit, and never less than one-eighth the capacity of the cylinder; and care must be taken in forming the passage between the condenser and air pump, to allow sufficient room for the injection water required for one stroke of the engine, besides a sufficient communication, otherwise the connection between the air pump and condenser will be stopped up by the water, as the cylinder is twice filled with steam for one stroke of the air pump.

212. *Air Pump.*—The dimensions of the air pump are gen erally such as to give one-fifth the capacity of the cylinder; hence, suppose the cylinder of an engine is 30 inches in diameter, and the stroke 7 feet, or 84 inches; required the air pump's diameter at half the stroke. The radius of the beam is 96 inches, the stroke 84, and the radius of the air pump studs is 48 inches, then as

$$96 : 84 :: 48 : 42, \text{ the length of stroke;}$$

and $$\frac{30^2 \times 48}{5 \times 42} = \sqrt{205.71} = 14.34 \text{ inches diameter.}$$

213. *Cold Water Pump.—Rule.* Multiply the area of the cylinder in feet by twice the length of the stroke, in feet, and that product again by 35 cubic inches, or 45 circular inches, the quantity sufficient for 1 cubic foot of steam, allowing for waste, &c., which divided by the length of stroke in inches of the pump, and the square root will give the diameter required.

Then suppose A is the area of the cylinder,

S twice the stroke also in feet,

45 circular inches=1 foot of steam,

l, the stroke of the pump in inches,

and d the diameter in inches.

$$\text{Then } \sqrt{\frac{A\ S\ 45}{l}} = d, \text{ and } \frac{A\ S\ 45}{d^2}\ l =.$$

Example.—What is the requisite diameter for a pump, the diameter of the cylinder being 2 feet 6 inches, and the stroke 7 feet; the stroke of the cold water pump to be 42 inches?

$$\sqrt{\frac{4.9\times14\times45}{42}} = 8.64 \text{ inches in diameter.}$$

214. *Fly Wheel.—Rule.* Multiply the number of revolutions per minute by the diameter of the wheel in feet, and by the product divide 1400 times the number of horses' power; the quotient is the weight of the ring, or rim of the wheel, in cwts.

Example. Required the necessary weight for the rim of a fly wheel of a 20 horse engine, making 24 revolutions per minute, the fly wheel being 18 feet diameter—

$$\frac{1400\times20}{24\times18} = 64.58 \text{ cwts.}$$

215. *Fly Wheel and Paddle Shafts.*—It must be remembered that where calculations of the strength and dimensions of shafts occur, the measurements apply only to the journals or bearings; and as the different purposes to which they may be applied, and the different material of which they may be made, require different multipliers, we here subjoin the following proportions, which are the result of experience:

216.	For cast iron shafts in land engines,	450
	For wrought iron paddle shafts for sea,	356
	For wrought iron paddle shafts for rivers,	194

General Rule. Multiply the number of horses' power by the multiplier corresponding to the purpose to which it is to be applied, divide the product by the number of revolutions per minute, and the cube root of the quotient is the shaft's diameter, in inches.

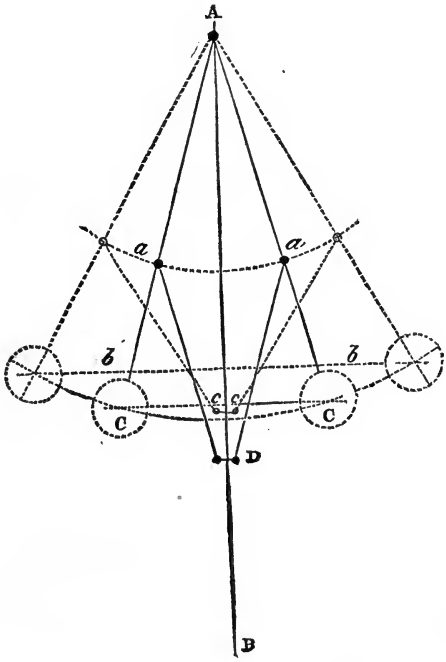
Example.—Required the diameter of a wrought iron paddle shaft for an engine of 40 horse power, making 25 revolutions per minute.

$$3\sqrt{\frac{356\times 40}{25}} = 8.28$$

217. *The Governor.*—The governor is attached to steam engines and other machines for the purpose of regulating the supply of steam or other power to the demand, or to the resistance to be overcome. In the steam engine, this is effected by the action of the centrifugal force acting on two balls, or weights, and by its increase or diminution, elevating or depressing their plane of gyration; the slightest variation in speed being instantly exhibited by a corresponding alteration in their position.

Suppose A B to be a vertical shaft, having a collar at D, which is attached to the arms of the balls C C by means of

DIAG. XIX.



rods which move on pins at their extremities *a a;* hence it is obvious that if the shaft A B is made to revolve rapidly on its

axis, the balls C C will fly off in the position shown by the dotted lines, and by such movement will have drawn the moveable collar D up the shaft into the position shown by the dotted centres *c c*; and if one arm of a lever or handle be attached to the collar, it will raise or depress that lever according to its extent of motion.

218. In adjusting the different parts of the apparatus, it will be necessary to consider the position of the balls corresponding to their mean velocity, the range of motion, and the weight and velocity of the balls.

The vertical distance between the point of suspension and the plane in which the centres of the balls revolve, is the same as the length of a pendulum which makes two vibrations in the same time the balls make one revolution. The usual velocity of the balls is 30 revolutions per minute; therefore, the height from centre of suspension to centre of balls should equal a second's pendulum, that is 39.14 inches. If any other number of revolutions are required, divide 35,226 by the square of that number.

219. *Example.*—Thus, 35 revolutions are required; what must be the height from the plane of revolution to the centre of suspension?

$$35^2 = 1225$$

$$\text{and } \frac{35226}{1225} = 28.756, \text{ height required.}$$

220. Or divide 375 by twice the number of revolutions, and the square of the quotient will be the height required.

Example.—What is the required height for 42 revolutions?

$$42 \times 2 = 84$$

$$\text{and } \frac{375}{84} = 4.46^2 = 19.8916 \text{ inches.}$$

221. Or thus, the height being known, required the number of revolutions.

$$\sqrt{19.9} = 4.46 \times 2 = 8.92,$$

$$\text{and } \frac{375}{8.92} = 42 \text{ revolutions per minute.}$$

222. The greatest variation should not exceed one-tenth of the velocity, that is, one-twentieth above and one-twentieth below the mean; and the range of the plane of revolution will be nearly one-fifth of the height of suspension above the plane of revolution at its mean velocity. Thus, the mean height being

$$39.14 + 3.914 = 43.054$$
$$39.14 - 3.914 = 35.226$$
$$\text{The difference} = 7.828$$

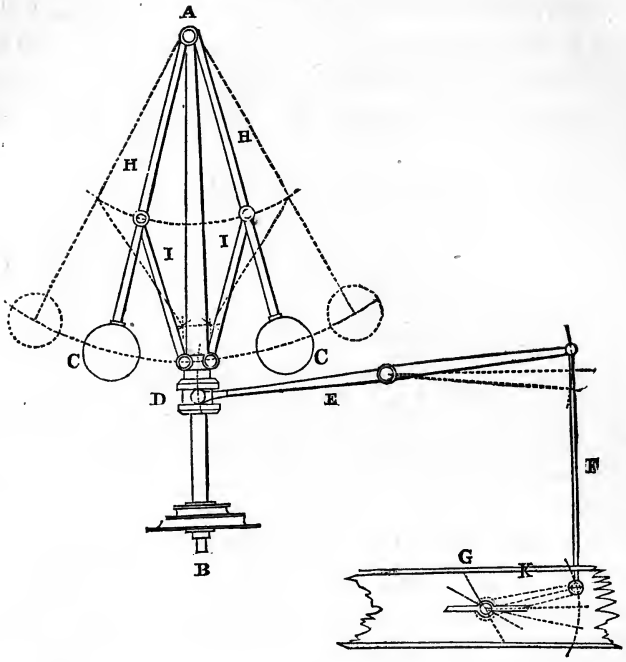
One-fifth of $39.14 = 7.828$.

The balls vary in weight from 15 to 80 lbs. each; and when at rest, should form an angle of about 30° with their axis.

223. The method of arranging the governor, lever work and throttle valve, is explained in the following diagram. A B, the upright shaft or axis of the governor, which receives motion by means of a cord passing round the pulley at B, and round a corresponding pulley on the crank shaft of the engine or other convenient part. C C the balls; D the moveable collar connected with the arms H H, by means of the rods I I, which move on pins at their extremities. E the lever, having a fork at one end, which rides in a groove in the collar D, and connected at the other end by the rod F to the throttle valve lever, shown by the dotted lines K. G is the throttle valve, which is shown wide open in the steam-pipe, the engine being supposed at rest.

224. The exact length of the levers must depend on the size of the valve and motion of the collar D, and can be arranged in the same manner as the eccentric levers.

DIAG. XX.



225. The dotted lines in the diagram exhibit the position of the balls, collar, and valve, when the engine is working at the maximum speed required; for the further adjustment, however, requisite upon change of temperature or from other causes, there is usually a turn-buckle on the rod F, by turning which, the engine may be made to receive more or less steam, as the work to be performed requires greater or less velocity, or to compensate for other causes. To find the requisite diameter of the two pulleys, or the number of teeth in the wheels to produce any given velocity, the following rule is to be used:

226. *Rule.* Multiply the diameter of the pulley, or number of teeth in the wheel on the governor spindle, by the velocity of the spindle, or number of revolutions per minute, and divide by the velocity or number of revolutions of the engine in the same time; the quotient is the pulley's diameter, or number of

teeth in the wheel on the fly-wheel shaft. Or, multiply the velocity of the engine per minute by the diameter of the pulley, or number of teeth in the wheel on the fly-wheel shaft, and divide by the required velocity of the governor; the quotient is the pulley's diameter, or number of teeth in the wheel on the governor spindle.

227. *Example* 1. Required the diameter of a pulley for the spindle of a governor, to perform 36 revolutions per minute; velocity of the engine 22, and the diameter of the pulley on the fly-wheel shaft 18 inches.

$$\frac{22 \times 18}{36} = 11 \text{ inches diameter.}$$

228. *Example* 2. Suppose the following case:—

The engine makes 34 revolutions per minute.

The governor, 52 revolutions per minute.

The pulley on fly-wheel shaft, 16 inches diameter.

The pulley on the intermediate shaft, 12 inches diameter.

Wheel on governor spindle, 40 teeth.

Required the number of teeth in the wheel on the intermediate shaft.

$$\text{Thus } \frac{52 \times 40 \times 12}{34 \times 16} = 46 \text{ teeth.}$$

229. *Example* 3. Again, suppose the engine and governor situated as above, required the diameter of the pulley on the intermediate shaft.

$$\frac{34 \times 16 \times 46}{52 \times 40} = 12 \text{ inches diameter.}$$

The weight of the balls in lbs. ought to be about $1\frac{1}{4}$ times the length of the pendulums in inches, and the levers to the throttle valve ought to be so adjusted that the greatest angle the arms form with the spindle may not exceed 45°.

230. *Piston Rods.*—The diameter of the piston rods for land engines with long strokes, or marine engines for sea-going vessels, $\frac{1}{10}$ of the cylinder's diameter; for land engines with short

strokes, and river engines $\frac{1}{12}$; for locomotives $\frac{1}{7}$ of the cylinder's diameter.

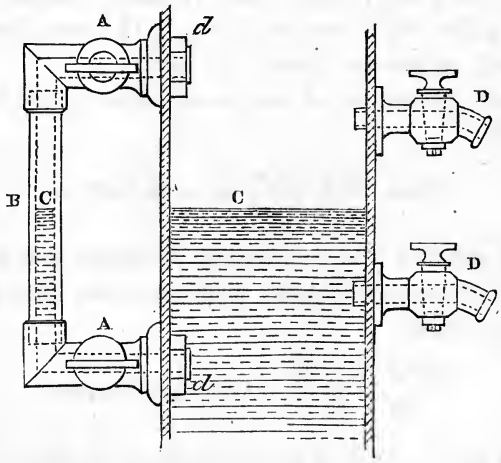
231. *Air-Pump Rods.*—Diameter of air-pump rods, $\frac{1}{10}$ of the pump diameter; if of copper $\frac{1}{8}$.

232. *Injection Cocks.*—Area of injection cock about .4 of an inch to each horse power; or make the diameter of the cock $\frac{1}{15}$ of the cylinder's diameter.

233. *Chimnies.*—The diameter of steam packets and locomotive chimnies equal the diameter of the cylinder; in vessels with only one engine, $\frac{2}{3}$ of the same.

234. *Water Gauge.*—Many methods have been adopted for ascertaining the level of the water in the boiler, but all of them are more or less faulty; the annexed diagram represents a method now generally adopted, where steam of high temperature is used.

DIAG. XXI.

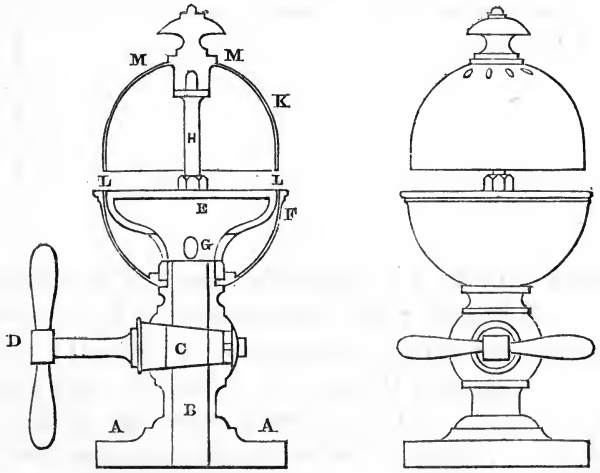


A A are two stop-cocks, secured to the boiler by means of nuts *d d*; B is a glass tube cemented into the cocks A A, and C the level of the water in the boiler; thus when the cocks are both opened, the water rises to its level in the tube, and the steam occupies the remainder; any variation of level is of course visible.

235. Another method is by gauge-cocks, of which there are two, and often three, attached to the boiler, which are opened and shut when the engineer pleases ; from the upper one steam is expected to blow off, and from the lower one water ; consequently when the level of water falls below D′, so that steam blows off, the engineer is prepared to remedy the evil ; and when water blows out of D, he is equally aware that no more water is then required.

236. *Steam Whistle.*—In consequence of the various accidents which occurred, and indeed which do continually occur upon rail-roads, many different schemes were tried for warning the public from the track on the approach of a locomotive engine ; amongst the most effective is the steam whistle, the invention of an ingenious artisan of Liverpool, England. The following is a description of it :—

DIAG. XXII.

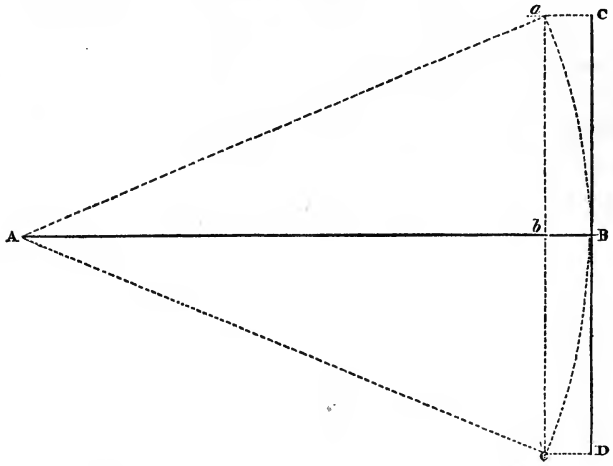


A A, the flange, by which it is attached to the boiler ; B, the passage for the steam into E, an inverted funnel with holes at G, to allow the steam to pass out between the cup F and funnel E, through the narrow opening L L, formed by the close proximity of the two ; the bell or cup K is fixed to the funnel E by means of the stem H, and the edge of the cup K is direct-

ly over the opening L L, at half an inch distance; there are small holes left in the bell at M M to allow the steam to escape. The handle D is made sufficiently large, to enable the engineer to turn on just so much steam as will produce the greatest effect. The whistle may be heard at a very considerable distance.

237. *Problems.*—To find the versed sine, the radius and chord being given.

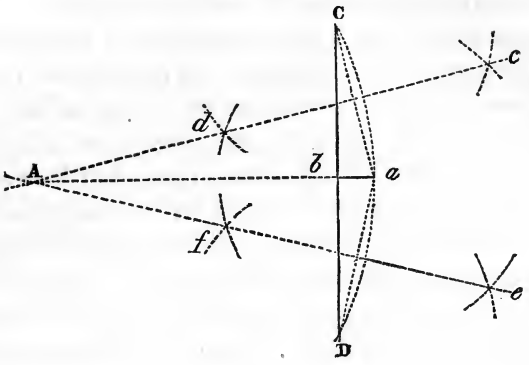
DIAG. XXIII.



Set off to a scale A B = the radius, and C D at right angles thereto = the chord; then, with the distance A B and centre A, describe the arc *a* B *c*; draw the lines *a* C and *c* D ‖ to A B, and cutting the arc *a* B *c* at *a* and *c*, join *a c*; then will *b* B be the versed sine. Or, numerically, as the diameter is to half the chord, so is half the chord to the versed sine, the result being divided by two.

238. To find the radius, the versed sine and chord being given.

DIAG. XXIV.

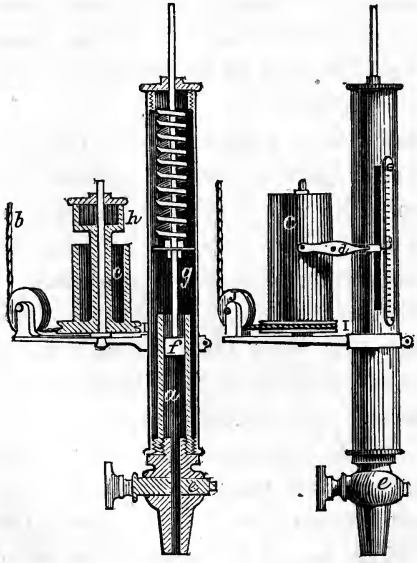


Let C D be the chord, and *b a* the versed sine; required the radius of the circle. With the centre *a*, and any distance *a c*, describe the arcs at *c*, *d*, *e*, *f*, and with centres C and D and the same radius, describe arcs cutting the former at *c*, *d*, *e*, *f*; draw straight lines through the points *c d* and *e f*, and the point A where the lines cut each other will be the centre, and A *a* the radius of the circle, whose versed sine and chord were given. Or, numerically, thus: as the versed sine is to half the chord of the whole arc, so is half the chord of the whole arc to the diameter, the versed sine being added.

239. *Steam Engine Indicator, or Dynamometer.*—This useful, and we may say valuable, machine, was first suggested by Mr. Watt, being one among the many important inventions of that truly great man. It appears, however, that the machine was improved by Mr. Southern, who put the sliding-board and counter-weight to it, with tracing-point. As a proof of the originality of the machine with Watt, there are, at this day, diagrams with the board and tracing-point, as far back as 1802, among the archives at Soho. The machine, as improved by Mr. Southern, was used until an ingenious mechanic of Glasgow, Mr. John Macnaught, added many valuable improvements. Our Cornish brethren have found that, without this instrument, it is very difficult to get the true and beneficial

effects of expansive steam; it is also used in many of the manufactories of that country. By it, the proprietor can ascertain, in one minute, the working condition of the engine; he can detect neglect in his engineer; can demonstrate the quantity of power required to overcome the friction of the engine, to give motion to the shaft and mill-gearing, or to drive the machinery. He can tell the power expended to drive any part of his works; or, if power is let off, he can at any time prove what power his tenant consumes; he can ascertain the friction of the machinery, when using different oils; and can guide himself, with certainty, in the choice of that which is best. He can ascertain the expenditure of steam, when injecting water at different degrees of temperature; and can compare the saving arising from the use of cold water, with the expense of procuring it. In fact, by this instrument, he not only can find out the most economical way of working his engine, but he can measure the expenditure, and regulate the distribution of power, at all times.

Diag. XXV.

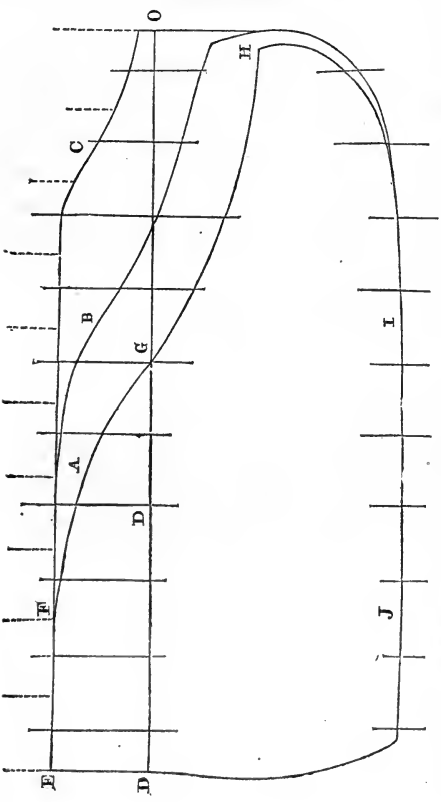


240. The cylinder of the indicator *a* is equal to $\frac{1}{4}$ of a square inch; the dimensions on the scale $\frac{1}{10}$ of an inch; each division representing 1 lb. of pressure on the square inch of the piston.

When the cock *e* is shut, the index will stand at 0, or zero; when open, the pressure of steam will be exhibited above 0, and the vacuum below.

The cock *e* should be placed in the grease-cock, on the cylinder cover of the engine, or a separate opening may be made for it; on opening the cock *e*, the small cylinder *a* becomes part of the engine cylinder, and the small piston *f* is acted upon in the same ratio as the piston of the engine; to the piston-rod *g* is attached the index hand *d*, in the end of which is affixed a pencil, which is acted upon by the piston *f*, when rising or falling, from the effect of either pressure or vacuum. The small cylinder *c* is covered with a sheet of paper, and at its upper extremity is a spring *h*, much about the size of a watch-spring; the horizontal pulley I has a cord *b*, passing from its edge around the perpendicular pulley J. By attaching the cord *h* to the radius bar of the engine, or at any other convenient place where the motion is equal to the circumference of *c*, it will readily be perceived, that from the movement of the piston *f* and the cylinder *c*, the paper will receive a curved line, (as shown in the accompanying diagram, which was furnished me by Mr. Peterson, the intelligent and very obliging engineer of the Steam Ship British Queen, which was taken during her voyage to New-York, in the month of May, 1840) showing the average pressure from $\frac{2}{8}$, $\frac{3}{8}$, and $\frac{4}{8}$, cut-off—the pressure in the boiler being at that time 6 lbs.; the annexed being an exact facsimile of the one taken.

DIAG. XXVI.



241. Supposing the paper to be fixed in the cylinder already described, and the pencil point turned back, and the cord *c* attached to the radius rod, as before described; the moment the stroke turns and the pencil point is thrown down, the line D will be described; which will be the atmospheric line, or line of zero. Then, at the turn of the next stroke, the cock *e* being opened, the pencil point will move from D to E, which will show the extreme pressure of the steam on the piston above that of the atmosphere. We will follow this line from E to F, which is the point of cut-off; following the line to G, it will show where the pressure of the steam gets below the line of zero, and decreases until the piston gets to the lower end of the stroke H, when the piston will turn and the line I J will show the amount of vacuum gained.

242. The curves A, B, C, being the curves of $\frac{1}{4}$, $\frac{3}{8}$, and $\frac{4}{8}$, cut-off.

243. To ascertain the result of each, you apply a scale of tenths and decimals, which will show lbs. and decimals of lbs., and get from each of the 10 divisions of the diagram marked *a*, *b*, *c*, *d*, *e*, *f*, the amount of effect produced by steam and vacuum; add these up and divide by the number of divisions, 10, and the result is the mean effective pressure throughout the stroke, the results are as follow:—

Average at $\frac{2}{8}$ cut-off, 17.62 lbs.
Do. " $\frac{3}{8}$ . . . . 15.93 "
Do. " $\frac{4}{8}$ . . . . 13.86 "

The pressure in the boiler being 6 lbs.

244. The following table will show the average working of the British Queen Steam-ship, from the time of her leaving Portsmouth until her arrival at New-York, in November, 1839.

TABLE XVII.

November.	Press. of steam per square inch, in lbs.	Expans. valve showing at what pt. of the stroke the cut-off took place.	Degree of vacuum on the condensed side of pist.—inches.	Revolutions of Engine per minute.	Speed of Ship, in knots, p. hour.	Consumption of coals p. hour. Cwt.	qrs.	Consumption of coals per day. Tons.	cwt.
4	4.7	2-8 cut-off.	29¼	10.4	7.6	23	3	28	2
5	4.9	2-8 "	29¼	9.5	6.4	25		30	
6	4.6	2-8 "	29¼	11.7	8.4	26		31	4
7	4.9	2-8 "	29¼	11.3	8.4	24		28	16
8	4.8	2-8 "	29¼	10.8	7.6	24		28	16
9	5.0	2-8 "	29¼	12.3	9.4	28		33	12
10	4.8	2-8 "	29¼	12.5	8.	25	2	30	12
11	4.8	3-8	29¼	11.	7.2	26		31	4
12	4.8	2-8	29¼	11.	7.6	27		32	8
13	4.9	2-8		9.	5.4	19	2	23	8
14	4.7	2-8 } 11 to 12, A.M.		8.	4.4	18		21	12
15	4.6	2-8		8.8	5.4	19		22	16
16	4.8	2-8	29¼	12.	7.6	27		32	8
17	4.9	2-8	29¼	12.	9.	27		32	8
18	4.5	4-8 10to12	29¼	12.8	9.2	27	2	33	
19	4.8	4-8	29¼	12.	9.	27	2	33	
20	3.3	3-8	29¼	13.	9.2	28		33	12
21	4.6	3-8 } 12 to 1.	29¼	12.5	7.4	27	1	32	14
22	4.7	3-8	29½	14.3	8.4	31	2	37	16
23	4.8	5-8	29½	15.01	10.2	33		38	12
		Consumption from noon until arrival at New-York,						16	
		" between London and Portsmouth,						70	
		Total consumption,					Tons	702	

PART VI.

DESCRIPTION OF PLATES.

DESCRIPTION OF PLATES.

PLATE I.—*Front and side elevation of Bolton and Watt's Twenty Horse Portable Engine.*

The side elevation shows in section the arrangement of the throttle valve, D valve, cylinder-casing, cylinder, piston, exhaust-pipe, condenser, air-pump, and hot-well; also, the positions of the governor, feed-pump, eccentric, crank, and fly-wheel, the detail of which is exhibited in plate 2.

The front elevation shows the space occupied by the engine, the valve-case, side-rods, balance-weight, fly-wheel, &c.

This kind of engine is in great repute, from the fact that very little foundation is necessary, as the cistern, condenser, air-pump, &c. are all within the engine itself. The bottom plate of the cistern is bolted to the floor, for which purpose lugs are cast upon it, as shown in plan (plate 2); upon reference to which, all difficulty in understanding the various movements, positions, &c., will be removed.

This is considered the most improved arrangement, as executed by Bolton and Watt, and is used in engines of all powers. The only difference existing is in the fact that engines of a larger power have stone cisterns instead of cast iron; and the columns supporting the spring beams are fixed to blocks of stone, instead of being fixed to the sides of the cistern, as is shown in this instance. Probably, of all arrangements for portable engines, that is to say, condensing engines, this is the best and most efficient; however manufacturers may differ in opinion.

PLATE II—*Contains a plan of the engine, and the governor in detail.—The plan of the engine:*

AAAA, the cast iron casing of the cistern.

BB, the dotted line, shows the position of the cylinder.

C, the exhaust-passage.

D, the exhaust-pipe.

E, the condenser.

FF, the injection-cock and pipe.

GG, the position of the D valve-case.

HH, the bonnet of the foot-valve.

JJ, the channel to the air-pump.

KK, the passage to the hot-well.

LL, the hot-well.

M, the passage to the hot water-pump.

NN, the hot water-pipe.

O, the hot water-pump.

P, the bonnet of the valve-box.

Q, the flange of the pipe.

R, the cold water-pump.

SSS, the lugs for bolting the machine to the foundation.

TT, the cistern.

W, the step or socket for the governor-spindle.

The Governor, in detail:

AA, the governor-balls.

B, the spindle.

C, the travelling collar; C, a section of the same; C, a plan.

D, the socket for the arms; D, a section; D, a plan.

EE, the arms.

F, the horns or arms for supporting the balls when at rest; F, a plan of the same.

GG, the links; G, a side view of one link.

HH, the bearing for a spindle; H, a plan thereof.

III, section, elevation, and plan of step.

J, the shaft which receives motion from the main-shaft.

KK, the bevilled wheels for transmitting motion.

LL, the governor-lever in plan and elevation, showing the fork or crutch.

MM, elevation and end view of the bearing of the shaft J.

PLATE III.—*The parallel motion complete, and in detail.*

FIG. 1—Represents the parallel motion as laid flat down.

AA, the front links; CC, the back links.

GG the parallel bars.

H, the piston-rod socket.

I, the piston-rod.

K, the pump-rod socket.

L, the air-pump rod.

M, the air-pump rod cross-head.

N, the piston-rod cross-head.

O, gudgeon of front links; R, gudgeon of back links.

FIG. 2—An elevation of the parallel motion.

B, the packing of the front link.

FIG. 3—B, a section of the same.

FIG. 4—A side view of strap of front link.

FIG. 5—CC, side view of back link.

FIG. 6—D, socket for parallel and radius-rod cross-bar.

EF, sections of the back link packing.

FIGS. 7-8—Side view of packing of back link, showing the joints, and slot for the key.

FIGS. 9-10—Side view and elevation of piston-rod socket, with keys and gib.

FIG. 11—Section of air-pump rod socket.

FIG. 12—Air-pump rod cross-head.

FIG. 13—Piston-rod cross-head.

FIG. 14—Elevation of parallel rod, showing the ends, and manner of attaching it to the cross-bar.

FIG. 15—Elevation of parallel bar, showing the brasses and slot, or chase, for the key for tightening the brasses.

PLATE IV.—*Portable Ten Horse Steam Engine, as made by W. Fairbairn & Co.*, giving a side and sectional elevation of the engine.

The cylinder is contained in the base or pedestal of the column.

The D valve is attached to one side of the cylinder, and worked by means of an eccentric and lever. There is a cross-stay which receives the end of the valve-rod, and steadies the motion. The piston-rod cross-head works in guides on the sides of the column; and the connecting rod is attached to the cross-head, as in a locomotive engine, or similar to the engine in plate 10.

The crank-shaft is supported by its bearing on the cap of the column, on which is the bevilled wheel for working the governor.

The feed-pump is placed on one side of the cylinder, opposite to the governor, and is worked direct from the piston-rod cross-head.

The exhaust, steam and feed-pipes, are conveyed under the floor.

From the engine already explained in detail, it will be needless to introduce letters of reference in this case; a careful examination of the plate will sufficiently explain what has not been noticed above.

The geering at the side is intended to show the facility of transmitting the motion from the crank-shaft.

This arrangement has been considered very good, and is decidedly valuable as taking up very little room (no inconsiderable advantage in a crowded city), being easily put up, and being rather ornamental than otherwise.

PLATE V.—*Sixty-five inch Cylinder Engine, erected by Messrs. Maudslay, Sons and Field, Chelsea Water Works:* London, 1837. An elevation of the engine pumps and air-vessels.

PLATE VI.—*Longitudinal section through the centre of the cylinder nozzles, beam and main pump.*

PLATE VII.—Fig. 1. Side elevation of the hand-gear, levers and rods, with expansion tappet, &c.

Fig. 2. Longitudinal section through the centre of one of the boilers, showing the steam-boxes, feed-heads, floats, &c.

Fig. 3. Front elevation of the hand-gear, levers and rods, with expansion tappet.

PLATE VIII.—Fig. 1. Front elevation of the boilers, showing the furnace-doors, steam-boxes, damper-pipes, feed-heads, &c.

Fig. 2. Transverse section of the boilers, showing the steam-boxes, pipes and stop-valves, safety-valves, and pipes.

Reference to Plate V.

A, Cylinder.
BBB, nozzles and valves.
CC, condensing cistern.
D, air pump.
E, eduction pipe to condenser.
F, expansion tappet.
G, damper barrel for regulating the valves.
H, main beam.
I, sliding counterweight.
KK, hoisting beams.
LL, cranes for raising cylinder and pump covers.
MM, catch pins.
N, cold water-pump.
OO, hot water-pump and air-vessel.
P, pump-rod.
QQ, well.
R, working barrel of main-pump.
SS, clack barrels.
T, air-vessel.
V, main pipe.

Not requiring, as yet, any machines of this description, and, in fact, having only a very small number of pumping engines in this country—though the time is fast approaching when such engines will be indispensable—we have taken this drawing and description from that very valuable work, "Tredgold on the Steam Engine," lately edited by W. S. B. Woolhouse, Esq., F. R. A. S., &c., and for which we beg to acknowledge our indebtedness to that gentleman, trusting that we, ere long, may be enabled to return the like benefit.

To return. This engine is single acting; the diameter of cylinder is sixty-five inches, and the length of stroke eight feet; the diameter of the working barrel of the main pump is twenty-five inches, and the length of the stroke also eight feet. The boilers are six feet wide, eight feet high, and twenty-five feet long.

The operation of this engine and its appurtenances being nearly similar to the common hand-gear engines, it is scarcely necessary to advert to it but for the purpose of explaining that its action is only in one direction, namely, during the descent of the cylinder-piston.

It may be explained as follows:

The progress of blowing through being accomplished, that is, opening the valves for the steam to pass from the boiler into the cylinder, and through the nozzles to the condenser, and thus expel the air, vapour, and water through the blow-valves and valves of the condenser, the three valves in front of the cylinder, upper steam-valve, centre equilibrium-valve, and lower eduction-valve, shut again, and the injection-cock opened, the steam and eduction-valves are opened; the former to admit the steam into the top of the cylinder, and the latter to admit its egress from

the bottom of the cylinder to the condenser. The equilibrium-valve remaining shut, the pressure of the steam acting above the piston, with the vacuum underneath it, is sufficient to move the piston; and as it approaches the end of the stroke, or bottom of the cylinder, the hand-gear tappets and catches operate—first, to shut the steam-valve; secondly, the eduction-valve; and lastly, when at the bottom of the stroke, to open the equilibrium-valve, and thus open the communication between the top and bottom of the cylinder. The counterbalance at the outer or pump end of the beam then exerts a force sufficient to move the piston up again, and transfer the steam from the top to the bottom of the cylinder, when the lower tappet shuts the equilibrium-valve, and the action of its catch releases the catch of the steam and eduction-valves, thereby admitting of their opening as before, and being the means of making the motion of the valves continuous.

The boilers are of wrought iron, upon the marine principle, securely stayed, and with safety-valves, feed-pipes, and the usual apparatus, with the addition of whistle-pipes, that old but effectual method of making known the deficiency of water in the boilers.

The structure of this engine admits of its being worked to the various heights required for street supplies, the chief means of regulation being the expansion-tappet and safety-catch; the latter acting when the stroke exceeds its proper limit.

The counterweight for adjusting the engine moves between guide-strips inside the beam; it is worked by a long screw, which (the cross handle being moveable) admits of the whole range of the weight between the catch pins when the engine is at work.

The main pump and clack-seats are fixed in a substantial manner; they are supported by four strong

iron beams, (through which very strong holding down bolts pass,) and they are steadied by iron plates fixed above and forced against the masonry. The supporting beams are fixed within four feet of the bottom of the working barrel, and the masses of stone above them are considerable.

The pump-clacks are of gun metal, fitted with wrought iron plates leathered; these are of large dimensions compared with the working barrel, and they are fixed in separate chambered seatings and held fast by distinct rods pressed down by set screws.

Duplicates of such of the parts as are liable to derangement are kept in readiness; powerful cranes and hoisting girders are fixed, and the various tools so arranged that the taking to pieces and repairing any part of the engine and pump, can be effected without loss of time.

The engine is calculated to raise 2250 gallons of water per minute.

The construction and execution of this splendid engine does ample credit to the skill and industry of the well known firm from whence it came.

PLATE IX. *Twenty horse high pressure Engine, made by Alexander Birkbeck & Son, Brooklyn.*

The arrangement usually followed in high pressure engines differs very little, if any, from that shown in the plate. In some instances, the valve-case stands inside the cylinder; and the feed-pump is worked from the back link. The cut-off is also added sometimes, but unless the purchaser has some reason for the alteration, the present form would be adhered to. The proportions are as follow:

Diameter of cylinder, ...	16 inches.
Length of stroke, ...	4 feet.
Length of beam, ...	13 feet 9 inches.
Length of connecting-rod, . .	10 " 2 "

Length of links, ... 2 ft. 0 inches.
Length of radius bar, ... 3 " 5½ "
Height of beam from foundation plate, 10 " 11 "
Width between plumber blocks, . . 1 " 5½ "
Number of strokes, ... 40

The slide is similar to that of the European engines, being the simple D valve. The governor, pumps and eccentric are all the same. The connecting rod is similar to those used in the river boats, and is undoubtedly better than the old-fashioned cast iron rod so long used.

PLATE X. *Horizontal engine and air-pump, used in the American Sugar House, N. Y., made by L. S. and T. W. Bartholomew.*

The form of engine most generally used is shown in the Plate.

The arrangement is, as nearly as possible, the same as in a locomotive engine; excepting that no reversing motion is here necessary.

The great facility of fixing and putting together, as well as their cheapness, will always cause this kind of engine to be much used.

This engine is used for the purpose of creating a vacuum, by means of the air-pump, which is laid down in the plan, for the purpose of crystallization. The stroke is 3 feet 4 inches; the connecting rod, 9 feet 5½ inches. The cut-off is used and worked by a camb on the crank-shaft; the valve being closed by means of the spring, shown by the dotted lines, beneath the bed timbers. The air-pump is worked by a crank on the end of the fly-wheel shaft.

PLATE XI. *Horizontal Engine, with Sugar Mill, made by Levi Morris & Co., Philadelphia.*

This Plate shows another arrangement for a horizontal steam engine.

In this machine, we have a bed or foundation plate

of cast iron instead of timber, and a brick foundation. There is a small invert of brick in which the rock shaft works, the bearings of the rock shaft being secured to the under side of the bed plate; which arrangement renders the working of the slide more steady.

The horizontal pipe attached to the side of the brick work, is for the purpose of using the exhaust steam in warming the water for the feed-pump; thereby saving fuel. This practice has in many cases been attended with very beneficial effects.

The end view shows the arrangement of the sugar mill, and gearing for driving the same.

The working parts of the engine are finished with great care and exactness, and the whole machine is good and serviceable; at the same time, the cost is comparatively small.

The demand for these machines is chiefly confined to the West Indies, for the purpose of making sugar.

PLATE XII. *Elevation and end view of the Steam Engine of the U. S. Mint at Philadelphia; arranged and laid down by Mr. Franklin Peale.*

The arrangement of this engine will be seen by inspection; but the many novel and ingenious adaptations will require more elaborate description. The close attention that has been paid to the order of architecture selected is very obvious in the entablature, the capitals of the columns, the ornamental tripod stand of the governor, the etruscan vase for the starting handle, and the *fret* work of the eccentric lever; the mouldings on the different bosses and shafts; the bonnets for the valve-cases; all sufficiently attest the talent and application of the maker.

The power is communicated, by means of a strap, to the room below, where it is distributed and again returned directly to the machine it has to drive; thus

preventing that noise and dirt which so generally attend the presence of gearing in a room.

The cord that works the governor is also conducted below, where the motion is transmitted to the spindle.

The novel method of adjusting the throttle-valve is very ingenious and clever, and is admirably calculated to effect the desired end.

The index for pointing out the excess or diminution of speed is well worthy of attention.

PLATE XIII. Fig. 1. A plan of the entablature, showing the arrangement of the plumber blocks, eccentrics, fly wheel and drum. *a a*, the entablature, supported on the columns, as shown by the dotted circles *n n*; *b b b*, the three plumber blocks; *c c*, the entablature for supporting the third or outer plumber block, and taking part of the strain of the main frame; *d d*, the fly wheel shaft; *e e*, the two cranks; *f*, the connecting rod end; *g g*, the two eccentrics, one working the half stroke and the other the regular stroke of the engine; *h*, the pulley for the governor motion; *k*, the fly wheel; *m*, the drum for transmitting the power of the engine, by means of the strap *l*.

Fig. 1 A. The form of the crutch of the connecting rod, which is necessary, to enable it to pass the feed pump in its stroke. This is forged, together with the rest of the connecting rod.

Fig. 2. A plan of the arrangement of cylinder and valve cases, also showing the direction of the steam passages. *a a*, the entablature; *b*, the cylinder; *c*, the half stroke valve case; *d*, the valve case; *e*, the cylinder lid; *f*, the gland of the stuffing box; *g*, the piston rod; *h*, the piston rod cross-head; *k*, the pump rod; *l l*, the ends of the fork of the connecting rod; *m*, the lid of the valve case; *m'*, the lid of the half stroke; *n*, the gland of the stuffing box for the valve rod; *n'*, the gland of the stuffing box for half stroke

valve rod; *o o*, flanges cast on the valve cases, by which they are secured to the entablature; *p* shows, by the dotted circle, the steam pipe; *q*, the eduction pipe; *r*, in both cases, shows the steam passage going from *c* to *d*; *s s*, the steam passage to top of cylinder; *t t*, the steam passage to bottom of cylinder; *u*, the cylinder bottom; *w*, the half stroke valve case bottom; *x*, the valve case bottom; *y*, the valve rod; *y'*, the half stroke valve rod; *z z*, two chipping pieces for fitting on the standard for stopping gear.

FIG. 3. A section of the half stroke valve-case, entablature and steam-pipe. *a a*, the entablature; *c*, the valve-case; *b*, the valve or slide; *r r*, the steam passage; *p*, the steam-pipe passing up one of the columns *d d*; *e e*, the capitals; *f f*, the joint by which they are connected to the columns; *o o*, the flanges for fixing the valve-case to the entablature.

FIG. 4 shows an end view of the valve-case with the bottom cover, *w*; *o o*, the flanges; *a*, the entablature; *e*, the capital; *f*, the joint.

FIG. 5, is a section of the valve, valve-case, steam passages, entablature, capitals, &c. *a a*, the entablature; *b*, the D valve; *d*, the valve-case; *e e*, the capitals of the columns; *f*, the joints; *d' d'*, the columns; *o o*, the flanges; *q*, the eduction or exhaust-pipe; *r r*, the steam-pipe leading from the half stroke valve; *s s*, the steam way to top of cylinder; *t t*, the steam way to the bottom of cylinder; *y*, the valve-rod.

FIG. 6. A section through the valve-case and valve, showing their transverse dimensions.

FIG. 7, is an elevation of the arrangement for throwing the eccentric rod out of gear.

a, the eccentric rod; *b*, the hook of the same; *d*, the enlarged part of the valve-rod working in the guide, *c*; *e*, the standard; *f*, the handle or lever moving on the joint *h*, and bearing the roller *g* attached to it; on which, when the handle *f* is raised

to a vertical position, the eccentric rod travels. *b'*, the pin on which the hook *b* rests, when in gear.

FIG. 8, is a plan showing the arrangement of the parts; the same letters refer to the same parts.

FIG. 9. End view, showing the position of the tightening screw *k*.

FIG. 10, shows the method of making the half rule joint *h*.

PLATE XIV. *Details of the Engine in the U. S. Mint.*

FIG. 1, is an elevation of the feed-pump. *a a*, the working barrel of the pump, which also acts as a guide for the piston-rod; the pump-rod being merely a continuation of the other. *b b'*, the two standards of the pump, of which *b'* is the receiving and discharge pipe. *c c c c*, ornamental framing for stiffening and securing the work.

FIG. 2. An end view of the pump, showing the method of fixing the working barrel *a* to the standard *b*, by means of the screws *d d*; the gland of the stuffing box being secured by means of the screw *e e*.

FIGS. 3, 4, and 3 A, are elevations and end view of the pump-valves; the same letters referring to the same parts in each figure. *a*, the valve; *b b*, the passages; *c c*, the metal forming the valve seat; *d d*, a strap with projecting pieces inside, which by pressing against *e e*, when the screw *f* is tightened, hold the bonnet *m* firmly in its place. *g*, a part of the connecting pipe which is fitted to *c c* with a ground joint and retained in its position by means of the set screw *h*, working in the plate *k* which is connected to the entablature by means of bolts passing through the holes *l l*.

FIG. 3 A, is a side view of the plate *k*, and set-screw *h*.

FIG. 4. An end view of the valve-seat and bonnet, and one of the passages, also showing the alteration of form in the passages requisite for preserving an equal

area of water-way, and keeping the whole arrangement as small as possible.

FIG. 5—shows an arrangement for a joint in the pipe; *a a*, the main piece; *b* an opening or passage running at right angles from the passage; *b'—c c*, bolts for the purpose of connecting the joint *e e*, the main piece *a a*, and a similar joint to *e e*, firmly together; *d d d d*, four holes which run through *a a* at right angles to the bolts *c c*.

FIG. 6—Shows the face of a joint, and the manner in which the passage *b* leaves the passage *b' b'*; *d d*, the bolts for connecting *a* to another piece, for the purpose of continuing the communication.

FIG. 7—Is an elevation of one of the fly-wheel or crank-shaft plumber-blocks.

a a, the body of the plumber-block; *b*, the cap; *c c*, the two brasses; *d*, the open space or bearing for the journal of the shaft; *e e*, two strong bolts which connect the plumber-block to the entablature, and are secured by means of the nuts *f f*, which also act as dowels for preventing motion in the bearing; *g g*, the bolts for securing the cap and its brass to the body of the plumber-block, which are also secured by the nuts *h h*, which act as the nuts *f f*, thus rendering any motion very unlikely; *n n*, two keys which bear against the lateral faces of a chase, cut in the underside of the block, on their outer sides, and against a packing piece *o* cast on the entablature, on their inner sides, tending to render the stability of the bearing still more secure; *l*, is a strap or projection on the cap for strength and ornament.

FIG. 8—Is the plan of the plumber-block, showing the nuts *k k*, the top of the bolts *g g*, and the turned edges of the brasses *c c*.

FIG. 9—Shows the arrangement of the starting-valve, throttle and safety-valves.

a a, the two pipes which conduct the steam from the boilers to the main pipe *b*.

c, the safety-valve; *d*, the valve-case, having an egress-passage *e* to conduct the blow-off steam away; *f*, the lever of the safety-valve; *g*, the top of valve-spindle, which presses against the lever; *h*, the fulcrum or centre round which the lever moves; *r*, a small hole for elongating the lever, if necessary; *k*, the starting-valve for shutting off the steam or letting it on; *l*, the valve-case; *m*, the stuffing-box and gland of the throttle-valve; *n*, a pipe connecting the throttle-valve with the starting-valve *k*; *o*, a bridle or bearing for retaining the screw *p* against the spindle of the valve *k*.

PLATE XV.—*Details of the Engine in the United States Mint.*

Fig. 1—Is an elevation of the tripod-stand and governor.

a, the base; *b*, the upright or shaft, branching out near the top into the arms *c c c*, which support the hollow circular plate *d*; *e*, the index; *f*, a socket through which the governor-spindle passes, and in which it revolves; *g*, a collar; *h h*, the centres of the links *k k*; *l l*, the upper ends of the links, where they are attached to the arms *m m*; *n n*, the upper extremities of the arms *m m*, where they are attached by means of pins to the spindle *r*; *o o*, the governor balls; *p p*, the arms or horns which sustain the balls when the machine is at rest; *q q*, two small friction rollers fixed on the arms *m m*, to enable them to move more easily in the slots of the arms as they diverge or converge to the centre of motion.

Fig. 2—Is a ground plan of the base, showing the form of the tripod.

a a a, the base; *b*, the hollow shaft or column.

Fig. 3—Is an enlarged plan of the under side of the circular plate *d*.

r, the spindle ; *s*, the index plate.

e, the hand or index.

f, a small spiral spring to counterpoise the weight of the rod *z*, in fig. 4.

v, a small plate fixed to the ring *a*, with a loop at each end, for the purpose of connecting the spring *f* to the weight or rod *z* ; *x x*, the two pullies round which the cord passes that sustains the weight or rod *z* ; *y*, a small plate which supports the pullies and weight.

w, a small ring of metal which surrounds the spindle *r*, and to which is attached the hand or index.

Fig. 4—Is an elevation of fig. 3, the letters referring as before.

Figs. 5, 6, and 7—Are enlarged sections of the spindle and collar.

r, the spindle.

p p, part of the two arms for supporting the balls; *h h*, the holes for the pins which connect the rods *k k* with the arms *l l* ; *g*, the collar through which the pin *a* passes, and which works in the slot *a'*.

b, the collar which receives the fork of the throttle-valve lever.

c c, the bevilled wheels by which the motion is transmitted from the fly-wheel shaft to the governor-spindle.

Fig. 8—Is a side view of Mr. Peale's new and delicate arrangement for adjusting the motion of the throttle-valve.

a, a small rod attached to the lever *f*, and provided with a screw *l*, which works in *c*, a segment or rack, moving on the same spindle *d* as the lever *k*, and fixed to *k*.

e e, two connecting rods which are attached to the levers *k h*, and transmit motion from the fork of the lever *f* to the spindle of the throttle valve *g*.

z, the weight or bar which rests in a small hole on the fork, and, by its weight, when the lever *f* descends, descends also, and when the lever rises by its connection with the spring, (see fig. 3) it rises also, and causes the index *e* to travel to the right or left of the centre of the plate *s*, as the speed of the engine increases or diminishes.

It will be obvious, therefore, that if the screw *a* is turned to the right hand or left, it will for each revolution either elevate or depress the rack *c* one tooth, and consequently alter the position of *k* and *h*; thus enabling the engineer to run his engine at what speed he pleases—the index *e* always pointing out when he exceeds or falls short of the mean.

PLATE XVI.—*Elevation of the Engine and Boilers of the Steam Packet "Neptune."*

This engine was constructed in the year 1837, for the purpose of taking passengers from New-York to Charleston, S. C., by Mr. James P. Allaire, of New-York. She performed her voyages with considerable regularity for several seasons; but, owing to accidents which occurred to other packets, the confidence of the public seemed considerably shaken, and the expenses of the voyage were too serious for the number of passengers conveyed. The vessel was bought by the Texian Government last year, and now runs regularly from Galveston to New-Orleans.

The arrangements differ little from the general arrangements of cross-head engines.

The chief dimensions are as follow:

Diameter of cylinder, ...	50 inches.
Length of stroke, ...	11 feet 6 inches.
Length of connecting-rod, . .	23 " 9 "
Height of cross-head, at top of stroke from kelson, . . .	42 " 5 "

Width between guides, . . . 8 feet 8 inches.
Diameter of paddle-wheel, . . 25 " 0 "
Number of strokes per minute, . 23

The ordinary poppet valves, and the usual method of lifting them, are used in this engine. The two views here given will sufficiently explain her other arrangements.

PLATE XVII.—*Plan of the Engine and Boilers of the Steam Packet "Neptune."*

The plan shows the disposition of the various parts, as also the position of the boilers, which are connected by a steam-pipe, working in a packed joint attached to the further boiler.

PLATE XVIII.—*Engine of the Steam Packet "Charleston."*

This engine was built at Philadelphia, by Levi Morris & Co.

The arrangement of the parts differs very little from that in the "Osceola."

The principal dimensions are as follow:

Diameter of cylinder, ... 48 inches.
Length of stroke, ... 9 feet.
Length of beam, ... 15 " 9 inches.
Length of connecting-rod, . . 19 " 0 "
Length of links, ... 7 " 10 "
Height of beam, from kelson, . 28 " 7½ "
Width between guides, . . . 4 " 0 "
Diameter of paddle-wheel, . . 28 " 0 "
Number of strokes per minute, . 23

PLATE XIX.—*Engine of the Steamboat "Osceola," as made by Mr. Adam Hull, New-York.*

This engine was arranged and made by Mr. Adam Hull, and has given great satisfaction. The work is well finished and put together. The 'Osceola' has long been considered one of the fastest boats upon the North river, either of her own class, or of any other.

The general arrangement of the engine will be seen on examining the plate, which represents an elevation and side view, showing the side-pipes, rock-shaft, valve-rods, spindles, injection-cock handles, and throttle-valve lever. The cut-off is closed by means of a spring attached to the rod, which is continued from the lever for that purpose.

The chief dimensions are as follow:

Diameter of cylinder, ...			31	inches.
Length of stroke, ...	11	feet.		
Length of beam, ...	17	"	9	inches.
Length of connecting-rod, . .	21	"	1	"
Length of links, ...	7	"	6	"
Height of beam, from kelson, .	31	"	0	"
Width between guides, . . .	3	"	6½	"
Diameter of paddle-wheel, . .	28	feet.		
Number of strokes per minute,	24			

PLATE XX.—Detail of balance-valves, shaft, cylinder, plumber blocks, and rock-shaft of steamboat 'Osceola.'

FIG. 1—Is a section of the top valves.

AA, the steam-valves.

A′A′, the exhaust-valves.

BB, the glands of the spindles.

CC, the bonnets of the valve seats.

DD, the guides or sockets of the spindles.

EE, the valve-case.

FF, the valve-spindles.

G, the steam-way, or port.

HH, the side pipes. [In this engine, the side pipes are connected to the valve-case by flanges.]

C′ the bonnet or cover of the side pipe.

FIG. 2—Is a plan of fig. 1.

SS, the bearings of the valve or lifting-rods.

T, the cap. Q, the steam-pipe.

c c c c, the holes for receiving the bolts by which the bonnets CC are retained to the valve-case.

FIG. 3—Is a section of the lower valves.

II, two rings turned to fit into the sockets of the valve box, marked KK, and receive the side pipes, so as to form a space for packing at *a a a a*.

MM, two openings left in the bottom, which are closed up with bonnets similar to C′, in fig. 1.

L, the exhaust-passage, opening to the condenser.

FIGS. 4, 4—Are the elevation and plan of one of the crank-shaft plumber-blocks.

a, the journal.

b b, the brasses.

c, the plumber-block.

d, the cap.

e, the nuts for securing the cap.

f f, two strengthening webs.

g g, two flanges for the purpose of securing the plumber-block more steadily to the frame.

h h, lugs for the retaining bolts.

k k k, bosses cast on the flanges for the bolt-heads to bear against.

x, the oil-cup.

FIGS. 5, 5—The main gudgeon plumber-block. The same letters refer to the same parts as in the previous figure.

FIGS. 6, 6—Are the plan and elevation of the lifting parts of the valve-rods.

a a, the valve-rod.

b b, the lifting face.

FIGS. 7, 7—Are the plan and elevation of the rock-shaft, showing the position of the wipers, and lever.

a a, the rock-shaft.

b b, the journals.

c, the socket for the starting-lever.

d, the eccentric-lever.

e e, the wiper-frame.

f f, the wipers or lifters.

FIG. 7 A—The end view of Figs. 7, 7.

g, a slot cut in the eccentric-lever for adjusting the eccentric-pin.

FIG. 8—A section of the cylinder, port, and piston.

A, the cylinder.

B, the piston-rod.

C, the piston.

G, the port.

FIGS. 9, 9—D, the cylinder bottom.

G, the port.

FIG. 10—shows the dimensions of the port.

FIG. 11—A plan of the cylinder.

EE, lugs cast on the cylinder to support the cross-head guides.

a a, the bolt-holes for securing the cylinder-lid.

FIGS. 12, 13—Elevation and side view of the eccentric.

FIG. 14—Plan of the shaft, showing the bearings and bosses for the paddle-wheel centre plates.

A, the shaft.

B, the main bearing.

C, the middle bearing.

DDD, the bosses for the centre plates.

E, the outer bearing.

F, the crank end, or neck.

PLATE XXI.—*Detail of the Bed-Plate, Air-Pump, Condenser, Foot-Valve, Cranks, Connecting-Rod, and Cross-Head of the Steamboat "Osceola."*

FIG. 1—Plan of the bed-plate.

A, the bed-plate.

B, the bottom of the condenser.

C, an opening to admit the air-pump.

D, an opening to admit the foot-valve.

FFF, chipping pieces left on, to make the joints.

FIG. 2—A side elevation of fig. 1.

E, a groove cast on either side to retain the foot-valve.

FIG. 3—An end view of fig. 1.

FIG. 4—A plan of one of the cranks.

a, the crank.

b, the collar to receive the crank-shaft.

c c, the webs on each side of the crank.

d d, two lugs for the purpose of keeping the wrought iron strap *f f* apart from the crank, and to increase the strength thereof.

g, the socket for the shaft.

h, the socket for the crank-pin.

e, the collar for the crank-pin.

FIG. 5—A side view of fig. 4, showing the dimensions of the crank and wrought iron strap. The letters refer to the same in each.

FIG. 6—A plan of the other crank.

This crank has no hole through the end at *e*.

FIG. 7—A side view of fig. 6.

k k, two holes for the purpose of receiving the bolts which confine the crank-pin to its place.

FIG. 8—A section of the air-pump, bucket, delivery-valve, and waste and feed-pipe.

G, the air-pump.

H, the air-pump rod.

K, the air-pump bucket.

LL, the two valves.

M, cast iron ring to retain the packing secured by screws to the bucket K.

N, the delivery-valve, which also acts as the air-pump lid.

O, the gland of the air-pump rod.

P, the hot-well.

Q, the waste-pipe.

R, the feed-pipe.

S, a small pipe for the purpose of drawing off the water.

FIG 9—A plan of the condenser; C, the condenser.

TT, two large flanges for securing the condenser to the frame of the engine.

L, exhaust-passage.

U, injection-passage.

a a a, small webs to strengthen the flanges.

b b b, bolt holes.

c c c, bolt holes in the side-flanges.

FIG. 10—Elevation of the condenser.

d d d, bolt holes for connecting the lower valve-case to the condenser.

The other letters are the same as in fig. 9.

FIG. 11—The piston-rod cross-head.

a, the cross-head.

b b, the journals for the two links.

c c, the arms to receive the brasses for the slides.

d d, bolt-holes.

e e, projecting pieces on the arms for securing the brasses.

FIG. 12—Front and side views of the piston-rod socket.

a, the hole for receiving the cross-head.

B, the piston-rod.

h, the piston-rod socket.

k, the cotter which connects the piston-rod to the socket.

g, the collar which embraces the cross-head.

FIG. 13—Elevation and plan of one of the brasses.

f, the brass.

d d d, bolt holes.

n, a chase cut in the brass to receive the packing for the side of the guide.

FIG. 14—The foot-valve.

E', the frame which slides down in the groove E. (See fig. 2.)

l, the valve.

m, the valve-spindle or pin.

FIG. 15—Front and side views of the connecting-rod.

a a a, the connecting-rod.

b, the fork or crutch to embrace the end of the beam.

c c, the brasses.

d d, the straps.

e e, the cotters.

f f, the gibs.

g g, the pins for connecting the stays to the main part.

h h, the stays.

k k, the two struts fixed to the main part by *l*, a wrought iron ring.

o o, nuts for securing the stays.

m and *n*, a key and gib for connecting the ends of the stays to the main part.

c' c', the brasses for the crank-pin.

d' the strap.

e', the key.

f, the gib for securing the brasses to the connecting-rod.

PLATE XXII.—*Elevation of the Engine of the Steamboat "Daniel Webster."*

This engine is similar to the engine of the steam packet "Neptune."

PLATE XXIII.—*Entire plan of the Engine, with the disposition of its parts.*

A, the cylinder.

B, the cross-head.

C, the steam-passage.

D, the exhaust-passage.

E, the valve-seat.

FFFF, the pillars.

GGGG, the timbers of the main frame.

HH, the main journals.

IIII, the cranks.

JJ, the valve-boxes of the pumps.

K, the foot-valve.

L, the air-pump.
M, the delivery-valve.
N, the hot-well.
O, the hot water-pipe.

PLATE XXIV.—*Front Elevation and Section of Steam-Pipes and Valves.*

AA', the steam-valves.
BB', the exhaust-valves.
CC', the bonnets.
DD', the valve-spindle guides.
EE', the valve-chambers.
FF', the exhaust-valve spindles.
GG', the steam-valve spindles.
H, the side-pipes.
K, the bed-plate.
L, the cylinder-lid.
M, the piston.
N, the piston-rod.
OO', the steam-ways, or ports.
PP, the steam-valve lifters.
P'P', the exhaust-valve lifters.
Q, the steam-pipe.
RR', the eduction-pipe.

PLATE XXV.—*Description of the Engine of the Steamboat "North America," constructed and built by Mr. James Cunningham, of the Phœnix Foundry, New-York.*

An elevation and end view, showing the arrangement and position of the different parts. The main dimensions are as follow:

Diameter of cylinder,	42 inches.
Length of stroke,	11 feet.
Length of beam,	17 feet 8 inches.
Length of connecting rod,	19 feet 7 inches.
Length of links,	7 feet 6 inches.
Height of beam from kelson,	32 feet.

Width between guides, 4 feet 5 inches.
Number of strokes per minute, 44 single.
Diameter of paddle wheel. 38 feet.

Great attention has been paid to the construction of this engine--strength and durability have been attended to. The frame is made of yellow pine, well jointed and bolted together; the mortices and tenons being well paid with white lead. The timber which bears the crank shaft plumber blocks, is firmly dowelled and bolted to the fore leg of the main frame, and further supported by large knees of oak, firmly secured to the kelson. The plumber block itself being also held down by four two inch bolts secured with large washers and nuts under the kelson. To prevent any lateral motion in the frame, it is stayed with a strong diagonal frame, which is also secured to the side frames by means of cross bolts, &c.

The arrangement of the working parts is simple and efficient. The handles for starting, stopping, and for the injection, are brought to one spot, thus enabling the engineer to attend instantly, when required. The arrangement of supporting the eccentric rod on a vibrating joint, renders the stopping and reversing much easier than without it; and by using the balance valves instead of the ordinary poppet valves, a child may almost work the engine.

PLATE XXVI.—*Details of the Engine of the Steamboat "North Am ica."*

FIGS. 1, 2, are sections of the balance valves, valve seats, side pipes, bonnets, glands, packing, and also show the dimensions and position of the ports.

In figure 1, A A, are the valves, which are ground truly into their seats, for the admission of steam; A′A′, are also truly fitted to their seats; these are for the exhaust. B B are the glands of the valve spindles F F, working through the bonnets C C.

DD are bonnets on the lower side of the valve box, with sockets to receive the lower end of the spindles FF, and thereby ensure a perfectly vertical motion. EEEE is the valve case, of cast iron. G is the port opening into the top of the cylinder. HH are the two side pipes. IIII are rings which are turned truly to fit the sockets of the valve box, and also to allow the side pipes to pass through them, thus forming a small chamber for packing, at *a*, *a*, *a*, *a*, which allows the side pipes sufficient liberty in expanding and contracting to prevent accident. *b*, *b*, *b*, *b*, are rings cast on the valve box, which also fit tight round the top of the side pipe.

FIG. 2, shows the arrangement of the lower valves; the letters corresponding to the letters in figure 1. K'K' are two bonnets attached to the lower side of the valve box for the purpose of closing up the two openings MM.

FIG. 3, is a side elevation of the valve box and side pipe, showing the connexion of the steam pipe Q. N is the spindle of the cut-off valve, which works through a stuffing box V, and rests in a step or socket V'. R is a bracket fitted with a brass and cap to steady the motion of the spindle N, as it is periodically acted upon by the lever X, which is connected by means of rods and levers to a camb on the main shaft, and is adjusted to suit the cut-off required. O is the spindle of the ordinary throttle valve, which works in a stuffing box W, and rests in a step or socket W'. The lever Y is attached to a handle, which is placed immediately within the reach of the engineer, and which he can open or shut at pleasure.

FIG. 4, is a plan of figure 3, and the letters refer to the same in each figure.

FIG. 5, is a plan of figure 2, showing the bearings of the valve or lifting rods SS, and the cap T for securing

the same. *c*, *c*, *c*, *c*, are the bolts which retain the bonnets CC in their places.

As the peculiar advantages of the balance valves are not generally understood, it will be proper here to give a short description of them.

The first account we receive of an attempt to make a balance valve similar in principle to those here described, is an experiment of Watt's, who applied a piston to the stem of the valve, fitted to a cylinder of the same diameter as the valve, on the opposite side of the passage, and the steam acting on the valve and piston equally, the difficulty of raising it was much reduced. The introduction of the slide valve, however, for a long time superseded its use ; and its present form has not been in operation any very great while. By referring to the plate, (26) it will be seen that the valves AA, on the left, (figure 1) are not of equal sizes in diameter, the upper being $11\frac{1}{2}$ inches, and the lower only $10\frac{1}{2}$; also the corresponding valves AA, on the right, in figure 2, have the upper one $11\frac{1}{2}$, and the lower $10\frac{1}{2}$. Again, A′A′ on the right, in figure 1, has the top one $10\frac{1}{2}$, and the under one $11\frac{1}{2}$; A′A′ figure 2, corresponding with them as before.

Now suppose the dotted circle *d*, *d*, *d*, figure 1, to be the opening of the steam pipe Q, and the valves marked AA, and AA to be opened ; the steam enters the cylinder at the upper port and what was in the cylinder is exhausted at the lower port, and vice versa. But here the peculiar and elegant adjustment is shown : when all is shut and there is a vacuum on either side, say the upper side of the piston, that vacuum will have a tendency to open A'A' and close AA on the steam side. But A′A′ on the steam side is opened at the same moment, so the tendency of the one to open, assists the tendency of the other to shut,

and as that tendency is merely the weight of the valve, plus the pressure on the ring, which is the difference between the areas of $10\frac{1}{2}$ and $11\frac{1}{2}$, which equals 17.27 square inches; say the pressure is 50 lbs. on the inch, the pressure on the ring will be 86,350 lbs.; to counteract this, we have 17.27 square inches, with a pressure of 14 lbs. on the inch, and $14 \times 17.27 = 241.78$; the difference therefore will be 621.72, and the weight of the valves added will make say 700 lbs., but when it is considered what a common poppet valve would require, it will indeed appear little. If the ordinary poppet valve were 11 inches diameter, it would require 4,751,50 lbs· and the slides, such as are used in the British engines, weigh, without the friction of the faces being taken into account, 3,920 lbs.; but as the starting lever has a power of 6 to 1, the engineer merely exerts a power of 116.66 lbs.

PLATE XXVII.—*Details of the Paddle Wheel of the Steamboat "North America."*

Fig. 1, shows the outside framing of the paddle-box, or as it is frequently termed, the wheel-house; also an elevation of the paddle-wheel, shewing the arrangement of the buckets, arms, centre-plate, &c. AA is the main waling which rests upon the transverse timbers BB, which project from the side of the vessel. C the main upright on which the outer bearing of the paddle shaft E rests; DD diagonal framing for rendering the upright C steady, and also for completing the truss formed by the four pieces. GG two lighter diagonals quartered into FF, which are morticed into AA, and firmly bolted together with I; the foot of I is morticed into H, which acts as a tie to confine the pieces FF to their places, thus forming a stiff frame work for the planking of the wheel-house, and supporting the outer end of the shaft.

KKK are the arms; LL battens by which the floats are attached to the arms; MM the float boards; N an inner ring of segments of wood for the purpose of staying the arms; O an outer ring of iron for further security; P the centre plate.

FIG. 2, is a plan of the paddle wheel, showing the arrangement of the floats, which gives this kind of wheel the name of "split bucket," and also shewing the diagonal bracing QQ, for the purpose of preventing vibration in the wheel.

FIG. 3, is an enlarged view of one of the floats, shewing the method of fastening the same to the arm. KK are the arms, three inches by six inches deep, of red pine; LL two battens of hard wood placed on the face of the float to retain it more firmly against the arm when the motion is reversed, about $5\frac{3}{4}$ inches wide at one end, and 4 inches at the other, and one inch thick; the float-board M, is 5 feet 3 inches long, 2 feet 4 inches wide and $1\frac{1}{2}$ inch thick; it is fixed to the arms KK, by means of straps passing round the arm, through the batten L and washer R, and held to its place by $\frac{5}{8}$ screws and nuts, as shown in figs. 3 and 4; it is also held by two $\frac{3}{4}$ inch bolts and nuts at TT.

FIG. 4. A side view of the method of attaching the same.

FIG. 5, shows the method of connecting the outer ring to the arms; *a*, *a*, *a*, is a strap of iron, half an inch thick and three inches wide, which goes round the end of the arm K, and by being riveted tight to the rings OO, keeps the arm steady in its place.

FIG. 6, is an elevation of the centre plate, showing the arrangement for fixing the arms. AAA is a plate with webs cast upon it, 16 in number, and at B they diverge to the periphery of the plate, thus forming 16 spaces 6 inches wide, and 16 smaller ones. In the wider spaces, holes are drilled or cast for receiv-

ing the $\frac{3}{4}$ bolts, which are used in fixing the arms to the plate. D is the hole in the centre, 14 inches diameter, by which the wheel is fixed to the shaft; C is the ring, which is made 2 inches thick and $7\frac{1}{2}$ wide, for the key chases. The plate A is one inch thick, as are also the webs BB.

FIG. 7, shows the thickness of the plate and width of the boss or ring C.

PLATE XXVIII.—*Detail of the Engine of the Steamboat "North America."*

FIG. 1, is a section of the upper part of the cylinder, with the piston.

a, is the piston-rod; *b*, the key for attaching the piston to the rod; *c c c c*, the piston showing the disposition of the metal; *d d*, bosses cast on the piston to receive the bolts for fixing the top of the piston *e e*; *h h*, holes to admit the nuts for setting the above named bolts; *k k*, small webs of metal cast on the upper plate for the purpose of strengthening the same; *ffff*, a number of small holes drilled diagonally through the edges of the plate and piston to allow the steam to act against the segments *g g g*, &c., and, by the nature of their form press them against the inside of the cylinder, in the manner of a wedge. This kind of packing is much used, and, from its utility and economy, is considered very good. *l l*, the metal of the cylinder; *m*, the top steam-passage or port.

FIG. 2 shows, by the dotted lines, the position of the bracket *n*, which is attached to the frame of the engine, as shown in the elevation (plate 25.)

FIG. 3. Section of the cylinder bottom, condenser, steamway, injection-passages, bed-plate, foot-valve, air-pump and bucket, delivery-valve and hot-well.

O, the cylinder bottom, which is dished out to receive the convex or lever side of the piston *c* (fig. 1);

p, the port or steam-passage; *q*, the exhaust-passage; *r r*, injection-passages, of which there are three; very strong flanges or brackets for securing the condenser are shown at *s*; *t*, is the bed-plate on which the condenser rests, and which is bolted to it through its lower flange; *v*, the air-pump, which is inserted into the bed-plate, and likewise fixed to it by means of bolts; *u*, is the foot-valve; *w*, the air-pump bucket; *x*, the delivery-valve, which is cast hollow, and has its lower edges where it rests on the air-pump filed true, so as to fit and form a good joint;—this serves a twofold purpose, namely, as the air-pump lid and delivery-valve. Its action is very simple and ingenious; for when the air-pump bucket arrives at a certain height, the lid is raised, and the water flows out all round, thus discharging more effectually and rapidly than by the common valve, and requiring little or no power to discharge, merely having the weight of the lid to raise. *y*, is the hot-well, made of copper, and riveted to the air-pump by means of the vertical flange as shown in the drawing; *z*, is the air-pump rod.

Fig. 4, is a plan of the air-pump bucket, showing the manner of attaching the clacks to the bucket.

Fig. 5, is a plan of the bed-plate, showing the dimensions of the passage from the condenser to the air-pump, and also showing the manner in which the foot-valve is secured to the air-pump, namely, by bolts and nuts, the holes for which are there laid down. *a a a a*, are four lugs cast on for the purpose of sustaining the pumps.

Fig. 6, is the plan of the condenser, showing the position of the exhaust-passage *g*, and the injection-ways *r r r*; *s s*, the two flanges; *b' b' b' b'*, four lugs, to which a flat ring is attached, about two inches wide, and half an inch thick, over which is stretched

a wire web, to prevent any pieces of chips or other matter from getting into the condenser and air-pump from the river, and interfering with the valves, thereby destroying the vacuum.

FIG. 7. A plan of the cylinder bottom O, and showing the size of the port or steam-passage *p;* also the arrangement of the pillars *c c c c c c*, which support the cylinder, and through which the bolts pass to secure the cylinder bottom and condenser together.

FIG. 8. A sectional plan of cylinder, showing the shape of the brackets *n n*, and their position on the cylinder; *d dd*, small brackets cast on the bottom of the cylinder, and also on the bottom of the condenser, to strengthen and sustain the flanges.

FIG. 9, is the plan of the top of the cylinder. *e' e'* are the flanges or lugs on which the guides for the piston-rod cross-head are fixed; *m*, is the port or steam-passage, and *f f* shows the width of the packing ring.

PLATE XXIX—*Represents an Engine and Paddle-Wheel of the Steamboat "Merrimac," in elevation and plan.*

The general arrangement of the engine will now be understood at a glance.

The steam enters through the starting-valve, the handle of which is seen in plan and elevation; thence to the side-pipe, and thence to the top or bottom of the cylinder, through the common poppet-valve; the method of opening which at any required stroke is fully explained in page 170. By this arrangement, the valves act as cut-off valves at once; the exhaust valves are opened by the ordinary whole stroke camb, which is the inner or lower one in the plan, and which, by means of a rock shaft and short connecting rod, transmits its motion to the two arms or wipers, which a. ain alternately raise the valve levers.

The feed and bilge pumps are worked from a vi-

brating or rock shaft, by means of a short connecting rod or link attached to the piston-rod cross-head and the end of the arm; on the axis of which is a cross piece, to the ends of which the pump-rods are attached.

The whole machine is strongly and compactly made, although in the most economical manner. The guides for the cross-head are bolted firmly to the bed timbers. The pine wood connecting rod is strengthened by continuous plates bolted together at top and bottom, and the brasses are retained, as is usual, by gibs and keys.

The crank is of cast iron, about $1\frac{3}{4}$ inches thick and 18 inches wide; thus taking up little room and retaining great strength.

The arrangement of the paddle-wheels is simple and effective.

The actual dimensions of these machines are as follows:

Diameter of cylinder,	$17\frac{1}{4}$ inches.
Length of stroke,	7 feet.
Connecting rod, (generally $3\frac{1}{2}$ times the length of stroke,)	$24\frac{1}{2}$ feet.
Diameter of paddle-wheels,	17 feet 4 inches.
Number of revolutions, from	20 to 30

PLATE XXX. *High Pressure Boat Engine, as used on the Mississippi.*

This plate shows an arrangement where one engine only is used, and where it is necessary to introduce the fly-wheel for assisting the cranks past their centre.

The working parts are generally similar to the engines of the 'Merrimac,' though they are more highly finished.

The camb shown in the elevation cuts off at $\frac{3}{8}$ of the stroke; the other camb, as before, being simply for the exhaust, or giving the whole stroke.

The arrangement of the camb-frame and slides is here shown, as also the camb-rod.

The feed-pump, bilge, &c. are like the others.

The coughing-box acts in the same manner, though it is carried up with a larger pipe, which is an improvement.

The crank, however, is different; the centre plate of the fly-wheel is shown with bosses cast on it between opposite arms, to the outer one of which the connecting rod end is attached, by means of the crank pin. By having two holes for the pin, should accident happen to one, the other could be attached in a short time; thus obviating the delay consequent upon breaking the crank.

The arms of the fly-wheel are of wood, to avoid the chance of breaking when the paddle-wheels come in contact with floating timber, or when she runs aground.

The dimensions of this engine are as follow:

Diameter of cylinder,	30 inches.
Length of stroke,	6 feet.
Connecting rod,	19 ft. 10 inches.
Diameter of paddle-wheel,	18 feet.

PLATE XXXI.—*High Pressure Boat Engine, as used on the Mississippi*—Continued.

The plan shows the disposition of the parts; the cranks are connected by means of a link, as is frequently done in other marine engines. There are four distinct bearings for each shaft, with a coupling box between the two nearest, for the purpose of disconnecting one wheel when any very sharp turn is to be made. This is effected in the 'Merrimac,' by stopping one engine; and is a safeguard of the utmost consequence in avoiding snags, rocks and any other sudden and imminent danger.

The other parts are the same as before, excepting that a little more expense has been incurred in rendering the finish of the work more sightly.

It would be needless to crowd this work with any more drawings of this kind of engine, as the two furnished are the only kind, strictly speaking, employed on the waters of the West; that is, with and without fly-wheels.

There is, however, another arrangement worthy of notice, which is, that the paddle-wheels in some boats are so planned as to be raised or depressed at pleasure, in case of getting into very shoal water. This is effected in various ways; as, by wedges, screw-jacks, tackles, &c.

We will now consider the boilers, used for generating the steam, attached to these engines. The pressure on the boilers amounts to from 35 to 150 lbs., and in many cases to 200 lbs., on the square inch. This, to unpractised ears, seems incredible; yet such is undoubtedly the fact. Nay, it is highly probable that even this enormous pressure is exceeded without the knowledge of the engineer; and here it may not be amiss to calculate the power of one of the engines with steam of 150 lbs. and cut-off at $\frac{3}{8}$ of the stroke.

Area of cylinder $= 30^2 \times 7854 = 706.36$.

Stroke 72 inches, cut-off 27 inches.

$$72 \div 27 = 2.66.$$

Hyp. log. of $2.66 + 1 = 1.963$.

150 lbs. per sq. in. $\div 2.66 = 56.76$ relative expansion; and $56.76 \times 1.963 = 111.43$ lbs., mean pressure per square inch. $706.36 \times 111.43 = 78{,}709.69$ lbs. pressure on piston. Now, 50 single strokes $\times$ 7 feet, length of stroke, $= 350$ feet, speed of piston per minute;

and $\frac{78{,}709{,}69 \times 350}{33000} = 834.7$ horse power.

But we must deduct the friction of the engine, with the atmospheric resistance, which, together, is equal to 18 lbs. per square inch.

Then, $\frac{706.36 \times 18 \times 350}{33{,}000} = 134.8$ horse power.

And 834.7 − 134.8 = 699.9, effective power of engine.

PLATE XXXII.—The boilers, as has already been remarked, are cylindrical, and vary in number and dimensions. There are, however, rarely less than three boilers for each engine; and where only one engine is used, generally six. The average dimensions are from 30 to 40 inches in diameter, and from 20 to 25 feet in length, with and without return flues inside.

The boilers of the steamboat 'Merrimac' are six in number, 34 inches diameter, 24 feet long, with a returning internal flue of 16 inches. The smoke is conveyed from the flues to two stacks by means of slanting pipes, three meeting on the one side and three on the other. The boilers are placed on a brick seating, which is contained in a wrought iron cradle rising up from the back of the fire grate gradually, towards the other end of the boiler, as shown by the side view. The plan of the boilers shows the arrangement of the steam pipes connecting the whole six boilers, and feeding from the connecting pipe in front.

The end view shows the arrangement of fire doors, chimnies, and holes for clearing out the flues. The feed-pipes for the boilers come in under the end most remote from the fire.

Were it not that these boilers are made of the best material—Pennsylvania boiler plate—many more accidents would certainly occur, as the peculiar nature of the iron is their greatest safeguard.

PLATE XXXIII.—*High Pressure Steamboat Boilers, with Return Flues, as used on the Mississippi.*

Here is another arrangement: there being eight boilers for one cylinder. These boilers are fixed in a cradle, as before, and supported from the timber by means of iron legs.

The feed-pipes and steam-pipes are similar to the other, as are also the flues and chimnies. The dimensions are as follow, namely :

Diameter,		33 inches.
Length,	22 feet	8 inches.
Size of flues,		18 inches.

The boilers have the power of producing 398.18 cubic feet of steam per minute, on ordinary occasions, and, when needed, could produce nearly double the amount. The expense of fuel in these boats is, of course, occasionally, very great indeed.

PLATE XXXIV.—*Boiler of the Steamboat "Independence," plying between New-York and Amboy, the mail route to Philadelphia and the South.*

This is the first boiler in which anthracite coal has been successfully used. It has 270 tubes, 6 feet long, and $2\frac{1}{2}$ inches in diameter.

A, is the fire-box.

B, the tubes.

C, the chimney.

D, the steam-room.

E, the water-bridge.

F, the grate-bars.

G, the fire-doors.

The proportion between the generating surface and fire grate is nearly 36 to 1, and between the fire grate and chimney 4 to 1.

PLATE XXXV.—*The Boiler of the Steam Ferry Boat "Essex," plying between New-York and Jersey City.*

This is a compound boiler, having 800 tubes, 400 being on each side of the fire-box. These tubes enter into two flues, which extend the whole length of the boiler, and communicate with the chimney by means of flues rising from their upper surfaces, and thence carried horizontally to the chimney. The water level of the boiler is about 8 inches above the top

of the upper flues. The arrows indicate the direction of the draught.

The proportion between the generating surface and fire grate is about 35 to 1, and between the fire grate and chimney 3 to 1.

The novel arrangement of this boiler will be better understood by reference to the plate, in which

A, is the fire-box.

B, the tubes.

C, the chimney.

D, the lower flues.

E, the upper flues.

F, the steam-room.

G, the steam-chest.

H, the swan-neck, or steam-pipe.

K, the grate-bars.

L, the fire-door.

Although, from the peculiar description of work performed by this boat, it would be hardly fair to compare the economy of her boiler, in regard to the consumption of fuel, with the boilers of those vessels that do not stop above three or four times in a voyage of 150 miles, (the "Essex" stopping, on an average, every twenty minutes throughout the day,) nevertheless, there is no other boiler, with whatever advantages it may possess, that performs with less than three and a half times the quantity of coal that it does.

PLATE XXXVI.—*The Boiler of the Steamboat "North America," plying on the North River, between Albany and New-York, one of the last built and fastest boats on the river.*

This is of a cylindrical form, and, externally, similar to the locomotive boiler. It has flues and return flues; the chimney is, consequently, over the fire-doors, and is carried up through the steam-chest.

The proportion of generating surface to fire grate

is 22 to 1, and the proportion of fire grate to chimney 4 to 1.

AA, the main flues.

BB, the return flues.

C, the chimney.

D, the steam-room.

EE, the steam-chest.

F, the bridge.

G, the fire-door.

H, the water-space.

K, the grate.

The blower is applied to this boiler, for the use of anthracite coal.

FIG. 1, represents a half end view, and half transverse section.

FIG. 2. A longitudinal section of the boiler.

PLATE XXXVII.—*The Boiler of the steamboat "New-York,"* Is arranged in a manner entirely different from any other, having neither a water front, back, or bottom.

A, the flue.

BB, the tubes, 250 in number, and $2\frac{1}{2}$ inches diameter.

C, the chimney.

D, the steam-room.

E, the steam-chest.

F, the bridge.

G, the fire-door.

H, the grate.

This boiler, although having a very large generating surface, does not give so great a proportion between it and the fire grate, as would at first appear—the fire grate itself being very large. The proportion, however, is 24.25 to 1; but the proportion between the fire grate and chimney is 14 to 1; the area of the grate being 70.5 square feet, which is considerably larger than the generality of boilers.

PLATE XXXVIII.—*The Boiler of the Steamboat "Osceola."*

This plate shows a longitudinal and transverse section of the boiler, having a water back, bottom, and a water back to the fire-box. It is constructed for the combustion of wood, and for that purpose is one of the most effective yet made.

A, the main flues.

B, the return flues.

C, the stack or chimney.

D, the steam-room.

E, the steam-chest, round the stack.

F, the back of the fire-box.

G, the fire-door.

H, the water-space.

The proportion of generating surface to fire grate is 25.13 to 1, and the proportion of fire grate to chimney 3.97 to 1.

PLATE XXXIX.—*Stephenson's Patent Locomotive.—Side Elevation.*

This plate represents a side elevation of Stephenson's patent locomotive engine, made in 1836, for the Messrs. Cubitt, contractors for constructing a part of the London and Birmingham Railway, where it was used for about a year and a half, when it was bought by the Company, and used by them for carrying ballast, and other similar work; in which work it is still probably used.

The engine here described, and shown in the engravings, contains the latest improvements, and is similar in construction to most of those used on railways in England and on the Continent.

Upon referring to the plate, the general disposition and arrangement of the parts will be seen.

The chimney, man-hole, safety-valves, steam-chest, whistle, reversing-lever, with the position of the wheels and pedestal. The tender is attached, and shows the break, placed between the wheels.

This arrangement is considered very good, and, as has been mentioned above, is in general use. The exact points of difference will be seen by referring to the description of Dunham's locomotive, (page 240) with the drawings. (Plates 44, &c.)

PLATE XL.—*Longitudinal Section of Stephenson's Locomotive Engine.*

This plate shows a longitudinal section through the boiler and cylinder, and likewise through the tender; the section below the boiler being taken through the right hand cylinder and crank.

AA, the boiler.
BB, the fire-box external.
C, the internal fire-box.
D, the grate-bars.
E, the tubes.
F, the smoke-box.
G, the chimney.
H, one of the cylinders.
I, the damper.
K, the feed-pump.
L, water-guage.
M, guage-cocks.
N, the lever safety-valve.
O, the safety-valve.
P, the man-hole.
Q, the pedestal.
R, the blow-off cocks.
S, the steam-pipe.
T, the steam-chest.
U, the valve-box.
V, the slide.
W, the cylinder bottom.
X, the piston.
Y, the piston-rod.
Z, the cross-head.

A', the guides.
B', the connecting-rod.
C', the cranked-axle.
D', the driving-wheels.
E', the eccentrics.
F', reversing eccentrics.
G', feed-pump cross-head.
K', the feed-pipe.
L', front wheels.
M', hind wheels.
N'N', side frames.
O', front frame.
P', hind frame.
Q', the pedestals.
R', the bearings of the axles.
S', the springs for driving-wheels.
T', buffers.
U', the platform.
V', the engine-pin.
W' the coupling.
X', the tender-pin.
Y', wrought iron frame.
Z', steam whistle.

PLATE XLI. — *Plan of Stephenson's Patent Locomotive, with Tender, and detail of reversing gear.*

PLATE XLII.—*End view of Stephenson's Patent Locomotive Engine.*

The letters refer to the same parts in each plate.

PLATE XLIII.—*Locomotive Engine, by H. R. Dunham.*

Front and side elevation of the engine, showing the arrangement of the boiler, cylinder, connecting-rod, wheels, feed-pump, guides, safety-valve, throttle-valve handle, and chimney.

This engine has drawn a load up an incline that was equivalent to 220 tons, gross weight, upon a level, (including engine and tender,) at a velocity of 14 miles

per hour, with the steam at the usual pressure of 50 lbs. in the boiler. The force required to perform this, moving at that velocity, is about 2050 lbs., which is equal to 77 horse power.

PLATE XLIV.—Fig. 1. Plan of the engine, showing the position of the parts of the engine. The cylinders are placed on each side of the smoke-box, with an inclination downwards to the centre of the crank-shaft, which is placed behind the boiler. The eccentrics, with their reverse motion gear, are placed under the engineer's platform, so as to be accessible at all times. The sockets for the starting-levers, and the safety-valves, are each exhibited in place.

Fig. 2. An elevation of the eccentrics and reverse motion gearing.

AA, the eccentrics.

B, cranked axle.

CC, the eccentric-rod frame.

D, the rock-shaft.

E, the valve-rod lever.

F, the valve-rod.

G, the arm of the reverse motion lever.

H, the reverse motion lever.

K, connecting-link. LL, eccentric-levers.

Fig. 3. Elevation of the rock-shaft, showing the valve-rod pins, bearings, eccentric-rod pins, socket-joint, and starting-lever sockets.

Figs. 4 and 5. Elevation of one of the wheels, showing the mode of connecting the crank to the nave of the wheel, by letting it into a recess cast in the wheel for that purpose, and further strengthened by shrinking wrought iron straps around the nave. This method has been much praised, for the following reasons: it leaves more room between the cylinders, strengthens most materially the cranked axle, and is much less liable to accident than the old method.

FIGS. 7 and 8. Elevation and plan of one of the eccentrics, showing the method of fixing the same into the axle.

PLATE XLV.—*Detail of Steam Cylinder, with Pump, Piston, Connecting-Rod, &c.*

FIG. 1. Section through smoke-box, showing the steam-pipe, exhaust-pipe, cylinder-cap, valve-box, and feed-pipe.

FIG. 2. Section of cylinder, steam-ways, slide, valve-box, oil-cup, and steam-pipe; also, a section of the feed-pump, showing the retaining and delivery-valves; by having two of which, the trouble occasioned by the hot water getting into the pump is obviated, and a certain effect from the pump secured. The piston, piston-rod, slides, and guides, with the cross-head and connecting-rod attached, are also shown.

FIG. 3. Front and side views of the connecting-rod ends, showing the brasses, straps, keys, and gibs.

FIG. 4. Plan of the piston, with the bottom plate removed.

FIG 5. Elevation of the piston, showing the joint in the metal packing ring.

FIG. 6. Section of the piston, showing the bosses for receiving the bolts which secure the bottom plates to the piston, and also the connecting-rod.

For a full description of this kind of piston, see the former part of this work. (Page 177.)

PLATE XLVI.—*Sections of the Boiler, with detail of Pedestal, Throttle-Valve, &c.*

FIG. 1. Transverse section of fire-box, showing the arrangement and number of the tubes, the dimensions of the steam-chest, situation of steam-pipe, and level of the water in the boiler.

FIG. 2. Longitudinal section of the boiler, fire-box, smoke-box, and lower part of the chimney. The throttle-valve is shown in its place, with its standard and valve-rod, and the connecting-pipe to the smoke-

box. The flange for receiving the connecting-pipe to the valve-box is also seen.

Fig. 3, is a plan of the throttle-valve, showing the dimensions of the steam-passages, and also the slot which limits the motion of the valve, and through which the pin passes, connecting the rod to the slide.

Fig. 4. A section of the slide, when the passage is full open, showing how the rod is connected to it by means of the bolt or pin.

Fig. 5, is an elevation of one of the pedestals, with the bearing of the axle, and the steel pin which transmits the pressure on the axle to the spring.

Fig. 6. An end view of the same, showing the bolts and nuts which secure the pedestal to the frame.

Fig. 7. A plan of the bearing, showing the position of the oil-holes, bolt-holes for securing the cap, the chase for the pedestal, and a section of the steel pin.

Fig. 8. A view of the under side of the same, with the mortices for receiving and securing the cap.

Fig. 9. An elevation of the bearing, showing the cap in place, and secured by the nuts.

Fig. 10. A plan of the cap, showing the space for receiving the waste oil.

PLATE XLVII.—*Elevation of Locomotive Engine and Tender, arranged by P. R. Hodge.*

This engine is unquestionably one of the simplest in construction of any yet manufactured. The greatest care has been taken to reduce the number of working parts and to render the operation of starting, reversing and stopping, as easy and quick as possible. Thus, there are two eccentrics on each side, which for further convenience are placed outside the frame, enabling the engineer at all times to see that each part is in working order; or in case of accident, immediately to remedy the same. The operation of reversing is performed by drawing back

the reversing handle, thus raising one friction roller and lifting one eccentric rod and lowering the other roller, causing the hook of the eccentric rod to receive the pin of the lever; the two corresponding levers are connected together by means of a tumbling shaft passing under the boiler. There are two engines on the New-Brunswick and Jersey City road of this construction, and their regular performance is highly satisfactory. The original plan of this construction was laid down by myself, in the year 1836, for Messrs. Rodgers, Ketchum & Grosvenor, the manufacturers, at Paterson, N. J.

PLATE XLVIII.—*Elevation of Locomotive Engine and Tender, by W. Norris, Philadelphia.*

In another part of this work, mention has been made of the performance of Mr. Norris's engines,—upon reference to the plate, it will become obvious by what means the extraordinary performance of these machines is effected. The truck frame is placed as far forward as possible; the boiler is long, thus affording room for a connecting rod of proper length; the axle of the driving wheels is placed in front of the fire box, thus bearing nearly $\frac{3}{4}$ of the whole weight of the engine; the wheels are small in diameter, and the length of stroke is increased; thus all the elements, forming a powerful machine, have been very judiciously brought together, and the result is truly astonishing; the introduction of these engines having nearly put aside the objections formerly so strongly urged against inclined planes, on account of the increased expenses attending the working of a stationary engine. The following is a summary of the performance of these machines: weight of engine 8 tons, cylinder $10\frac{1}{2}$ inches diameter, stroke 18 inches. Weight which this locomotive can draw up the several grades specified on the next page, and on a level, at the speed of 15 miles per hour.

TABLE.

369	feet	rise	per	mile,	"	16	tons.
150	"	"	"	"	"	43	"
100	"	"	"	"	"	52	"
90	"	"	"	"	"	56	"
80	"	"	"	"	"	63	"
70	"	"	"	"	"	69	"
60	"	"	"	"	"	78	"
50	"	"	"	"	"	90	"
40	"	"	"	"	"	104	"
30	"	"	"	"	"	126	"
20	"	"	"	"	"	158	"
10	"	"	"	"	"	213	"
Level,		"	"	"	"	309	"

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ERRATA ET CORRIGENDA.

PAGE 65, Line 5—For ingenuous, read ingenious.

— 77 —

A, Tubular boiler, with return flue.

B, The cylinder.

C, The beam, supported at the smaller extremity on a rocking centre, and steadied by means of the radius-rods, one of which is shown attached to the upright, behind the cylinder.

D, The fly-wheel.

E, The reservoir, for the supply of the boiler.

F, The feed-pump.

G, The valve of the feed-pipe.

H, The grate-bars.

I, The stack or chimney.

1, The connecting-rod.

2, The fly-wheel shaft, with the geering.

3, The valve.

4, The exhaust-pipe, which conveys the steam from the cylinder into the reservoir E, where it is used for heating the water for the supply of the boiler, thereby causing a saving in fuel.

5, The feed-pipe.

6, The feed-pipe, showing where it enters the boiler.

7, The stop-valve of the feed-pump.

8, The starting and stopping valve.

9, The pump for supplying the reservoir.

Page 126, Art. 111.—For "insufficiency of the engines," read inefficiency of the engineers.

Page 145.—The credit of being the inventor of the reversing-face is due to Mr. Eastwick, the very intelligent partner of Mr. Harrison. These enterprising gentlemen have lately made very great improvements in Locomotive Engines.

Page 149, Art. 174—For "a = the diameter," &c., read d.

Page 172.—The reader will be kind enough to transpose Diag. XIV., inverted through the carelessness of the printer.

[*over.*

Errata.—Page 140. *Art.* 149.

TABLE OF DIMENSIONS OF LOCOMOTIVE ENGINES.

	Diam. of Cylinder.	Length of Stroke.	Diam. of Boiler.	Length of Boiler.		No. of Tubes.	Diameter of Tubes.	Area of Tubes.	Area of Fire-box.	Area of Fire Grate.	Quantity of Fuel in Fire-box.	Diam. of Chimney.	Weight of Engine.				Weight of Driving Wheels.	Diameter of Driving Wheels.	
	Inches	Inches	Inches	Ft.	In.		Inches	Feet.	Feet.	Feet.	Feet.	Inches	Tons.	cwt.	qrs.	lbs.	Lbs.	Ft.	In.
Uncle Sam,	11	18	38	6	11	122	1.75	386	35	7.25	22	13	10	9	3	3	11,375	4	6
Narragansett,	$10\frac{7}{8}$	16	38	6	3	124	1.50	304	40	8	24	12	9	15	1	22	10,885	4	6
Jupiter,	11	16	33	6	6	79	$1\frac{5}{8}$	226.80	36.06	6.08	11.12	12	7.9					5	0
Vulcan,	11	16	36	6	6	107	$1\frac{5}{8}$	307.38	34.45	6.50	7.64	13.5	8.34					5	0
Arresseoh,	11	18	$37\frac{1}{2}$	8	0	111	$1\frac{7}{8}$	435.89	39	7.4	24	$15\frac{1}{2}$	9	18	1	11	14,125	4	6
N. Brunswick,	$10\frac{1}{2}$	16	39	6	2	83	2	268	32	6.5	7.50	12	9	9	1	14		4	6

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